AD-A060 678 AIR FORCE SPECIAL WEAPONS CENTER KIRTLAND AFB N MEX --ETC F/G 17/9
THE NEED FOR TRACKING SYSTEM CAPABILITY VERIFICATION/CALIBRATIO--ETC(U)
AUG 75 E J POLLOCK

UNCLASSIFIED TM-117 SBIE-AD-E200 202 NL

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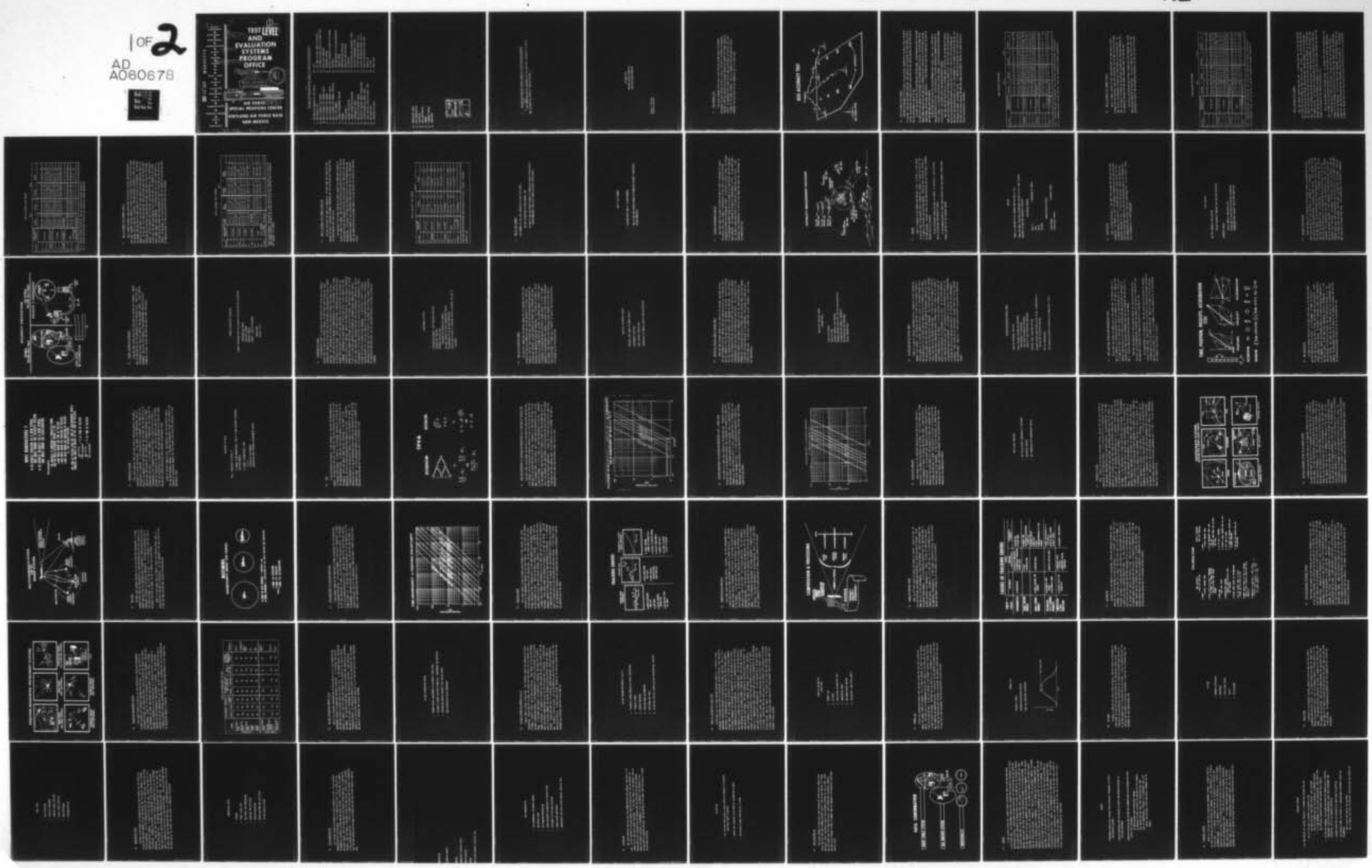

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ADE-200 202

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PROJECT MANAGEMENT
●
DEVELOPMENT
●
MEASUREMENTS
●
INSTRUMENTATION
●
SYSTEMS
●
TRACKING
●
TARGETS
●
TEST
●
OPTICS - LASER
●
TELEMETRY
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EVALUATION
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ENGINEERING
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ANALYSIS
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COMMUNICATION
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SIMULATORS

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TEST LEVEL II AND EVALUATION SYSTEMS PROGRAM OFFICE

(9) TECHNICAL MEMO[redacted]UM NUMBER 11

(6) THE NEED FOR TRACKING SYSTEM CAPABILITY VERIFICATION/CALIBRATION.

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AIR FORCE SPECIAL WEAPONS CENTER

KIRTLAND AIR FORCE BASE

NEW MEXICO

409 431 Gen

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THE NEED FOR TRACKING SYSTEMS CAPABILITY VERIFICATION/CALIBRATION

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1. <u>THE NEED FOR TRACKING SYSTEMS CAPABILITY VERIFICATION/CALIBRATION</u>

THIS ~~BRIEFING WILL~~ report is BE CONCERNED WITH THE NEED FOR A CAPABILITY TO VERIFY AND CALIBRATE ALL SORTS OF TRACKING SYSTEMS.

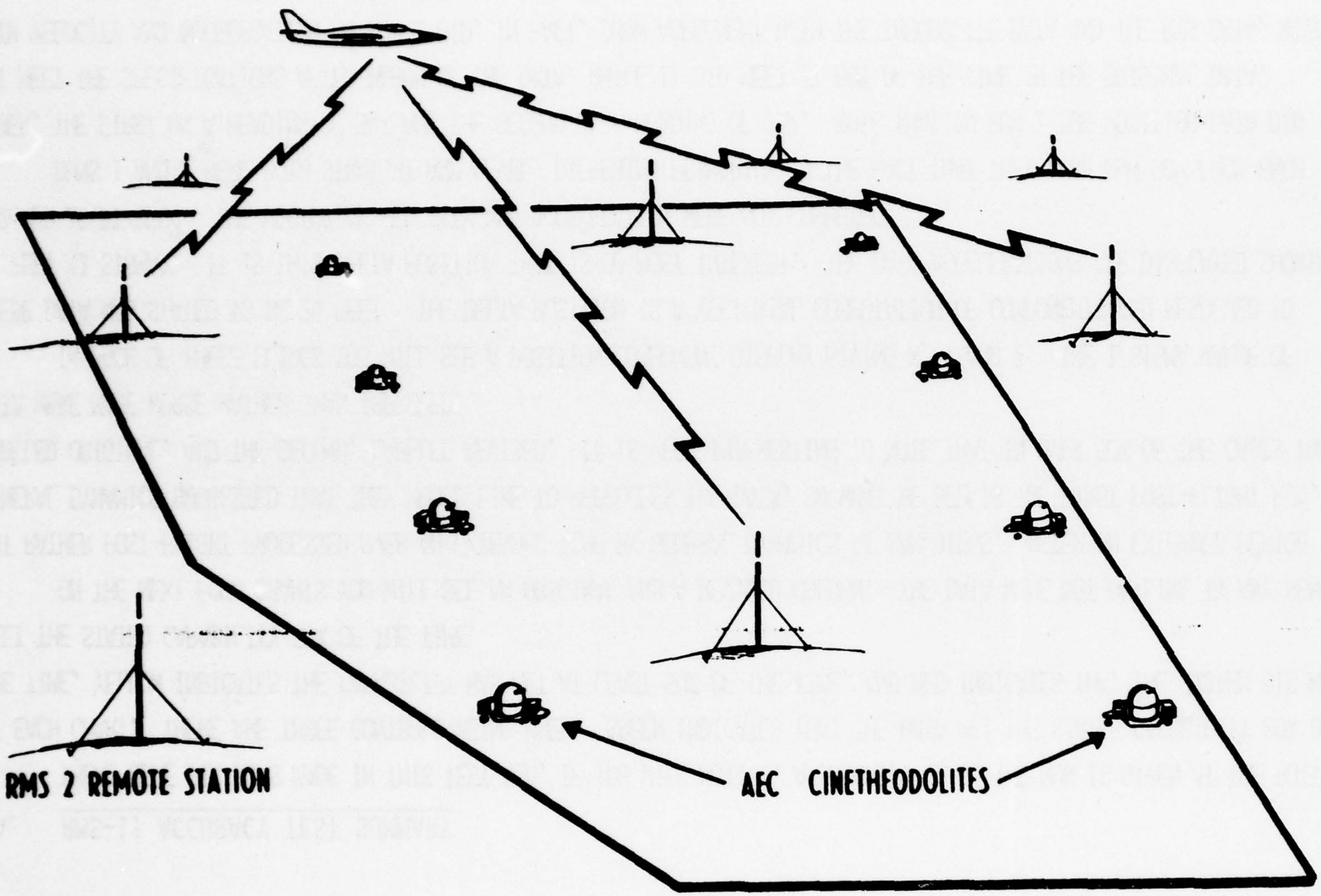
THE NEED FOR
TRACKING SYSTEM CAPABILITY
VERIFICATION/CALIBRATION

EUGENE J. POLLOCK
TECHNICAL ADVISOR

2. RMS ACCURACY TEST

THIS SLIDE CONCERNS ITSELF WITH A TEST THAT WAS ACCOMPLISHED A FEW MONTHS AGO DURING THE EWJT EXERCISE IN WHICH, LUCKILY, THE RMS-II ELECTRONIC DISTRIBUTED TRACKING SYSTEM WAS IMPLACED OR COLLOCATED AROUND THE TONOPAH TEST RANGE THEODOLITE SYSTEM. WE CONSIDERED THIS A RARE BIT OF GOOD LUCK BECAUSE, AS YOU WILL SEE, SUCH A CHANCE AS THIS RARELY HAPPENS. THIS IS A SCHEMATIC ONLY AND DOES NOT EXACTLY REPRESENT THE TRUE LAYOUT OF THE THEODOLITE, BUT IT IS VERY CLOSE.

RMS ACCURACY TEST



3A. RMS-II ACCURACY TEST SUMMARY

THERE WERE SIX RUNS MADE IN THIS TEST AND, IF YOU WILL NOTICE, A DESCRIPTION OF THE RUN IS GIVEN AT THE BOTTOM OF EACH CHART. THERE ARE THREE CONTROLS BEING USED. GREEN INDICATES THAT THE DATA MET THE STATED CAPABILITY 80% OF THE TIME, YELLOW INDICATES THE CAPABILITY WAS MET AT LEAST 50% OF THE TIME, AND RED INDICATES THAT THE SYSTEM DID NOT MEET THE STATED CAPABILITY 50% OF THE TIME.

ON THE NEXT FOUR CHARTS YOU WILL SEE AN ORIGINAL AND A REVISED COLUMN. THE DATA WERE NOT ON-LINE IN ANY SENSE, BUT RATHER POST-FLIGHT PROCESSED OVER AN EXTENDED TIME BY GENERAL DYNAMICS AT SAN DIEGO. AFTER AN EXTENDED PERIOD GENERAL DYNAMICS SUGGESTED THAT THEY WOULD LIKE TO REPROCESS THE DATA, SO WHAT WE SEE IS THE FIRST POST-FLIGHT RUN, LABELED ORIGINAL, AND THE SECOND, LABELED REVISED. IT IS VERY INTERESTING TO NOTE THAT IN OVER 50% OF THE CASES THE DATA WERE MADE WORSE RATHER THAN IMPROVED.

IN EACH OF THESE SLIDES YOU WILL SEE A POSITION COMPONENT DISPLAY GIVING X, Y AND Z. THE 1 SIGMA VALUE OF THESE DATA WAS STATED TO BE 25 FEET. THE DELTA POSITION IS A VECTORIAL COMPUTATION OF COMPONENTS AND RESOLVED TO 43 FEET (1 SIGMA). IT IS THIS DELTA POSITION THAT IS OF MOST INTEREST. THE DATA ACCELERATIONS ARE DISPLAYED SHOWING 1/2G OR 16 FT/SEC^2. THE VECTORIAL VELOCITY AND ACCELERATION WERE NOT COMPUTED.

RUNS 1 AND 2 WERE BOTH STRAIGHT AND LEVEL, DIFFERING PRIMARILY IN THE FACT THAT THEY WERE RUN 90^{o} FROM EACH OTHER, THE FIRST ON A HEADING OF 347 AND THE SECOND ON A HEADING OF 257. NOTE THAT IN RUN 1 THE POSITION DATA DID NOT MEET THE SPECIFICATIONS AFTER RERUN OF THE DATA, WHILE IT DID MEET IT 60% OF THE TIME IN THE ORIGINAL DATA. BOTH VELOCITY AND ACCELERATION ON RUN 1 DID, IN FACT, SHOW AGREEMENT WITH THE THEODOLITE DATA AND THE RMS DATA, WITH THE ORIGINAL DATA SHOWING A 75% AGREEMENT (YELLOW). IT IS IMPORTANT THAT WE RECOGNIZE THAT IN THESE CASES THE AIRCRAFT WERE FLYING STRAIGHT AND LEVEL AND SHOULD HAVE SHOWN ZERO ACCELERATION; THEREFORE, ANY SERIOUS DEVIATION IN VELOCITY OR ACCELERATION IS INEXCUSABLE.

RMS-II ACCURACY TEST SUMMARY

PAR EVAL	RMS-II Stated CAPABILITY	RUN 1 ORIGINAL %	RUN 1 REVISED %	RUN 2 ORIGINAL %	RUN 2 REVISED %
Δx		+7 to -33 (90)	+2 to -23 (100)	+12 to -37(90)	+52 to -100 (55)
Δy	25 FT (1σ)	-23 to +2 (100)	+5 to -15 (100)	+20 to -18(100)	+68 to -52 (95)
Δz		-45 to +115 (60)	-110 to -5 (5)	410 to -60 (5)	+400 to -975 (5)
Δ POSITION	43 FT (1σ)	10 to 115 (60)	110 to 0 (40)	410 to 20 (5)	10 to 980 (10)
Δvx		+16 to -17 (98)	-8 to +9 (100)	+23 to -22 (90)	+28 to -68 (95)
Δvy	15 FT/SEC	+15 to -15 (100)	-7 to +6 (100)	+20 to -23 (95)	+38 to -37 (95)
Δvz		+40 to -30 (75)	+16 to -16(99)	-120 to +105(25)	+90 to -230(70)
Δ VELOCITY	25 FT/SEC	NOT REDUCED			
Δax		+9 to -11 (100)	-2.5 to 4 (100)	+14 to -14 (100)	+10 to -24 (99)
Δay	ACCEL	+11 to -10 (100)	-2.5 to 3.5(100)	+16 to -15 (98)	+16 to -16 (100)
Δaz	0.5g (16 ft/sec)	+16 to -12 (100)	-3 to 5.5 (100)	-32 to -25 (20)	+27 to -32 (98)
Δ Accel	28 FT/SEC/SEC	NOT REDUCED			

RUN 1 - STRAIGHT AND LEVEL, 400-500 KTS TAS, 15KFT MSL, DURATION-84 SECONDS, HEADING-347°

RUN 2 - STRAIGHT & LEVEL, 400-500 KTS TAS, 10KFT MSL, DURATION-92 SECONDS, HEADING-257°

3B. <u>RMS-II ACCURACY TEST SUMMARY (RUN 2)</u>

RUN 2 IS ALMOST A REPEAT OF RUN 1 AND SHOWS ABOUT THE SAME KIND OF EFFECT, ALTHOUGH THE POSITION DATA, EVEN AFTER PROCESSING, DID NOT MEET THE SPECIFICATIONS AND, IN FACT, WAS DECREASED, ALTHOUGH NOT SIGNIFICANTLY ON THE REVISED DATA. ON RUN 2 THE VELOCITY ESTIMATES ON THE ORIGINAL RUN WERE VERY POOR WHEN COMPARED WITH THE THEODOLITE AND RMS DATA AND SHOWED IMPROVEMENT UNDER THE REVISED DATA.

THE INITIAL ACCELERATION DATA ON RUN 2 SHOWED VERY POOR AGREEMENT AND, AGAIN, WERE REVISED UPWARD ON THE RERUN DATA. THIS WAS A STRAIGHT AND LEVEL FLIGHT, AND DEVIATIONS OF VELOCITY AND ACCELERATION DIFFERENCES ARE VERY DIFFICULT TO EXPLAIN.

RMS-II ACCURACY TEST SUMMARY

PAR EVAL	RMS-II Stated CAPABILITY	RUN 1 ORIGINAL %	RUN 1 REVISED %	RUN 2 ORIGINAL %	RUN 2 REVISED %
Δx	25 FT (1σ)	+7 to -33 (90)	+2 to -23 (100)	+12 to -37(90)	+52 to -100 (55)
Δy		-23 to +2 (100)	+5 to -15 (100)	+20 to -18(100)	+68 to -52 (95)
Δz		-45 to +115 (60)	-110 to -5 (5)	410 to -60 (5)	+400 to -975 (5)
Δ POSITION	43 FT (1σ)	10 to 115 (60)	110 to 0 (40)	410 to 20 (5)	10 to 980 (10)
Δvx	15 FT/SEC	+16 to -17 (98)	-8 to +9 (100)	+23 to -22 (90)	+28 to -68 (95)
Δvy		+15 to -15 (100)	-7 to +6 (100)	+20 to -23 (95)	+38 to -37 (95)
Δvz		+40 to -30 (75)	+16 to -16(99)	-120 to +105(25)	+90 to -230(70)
Δ VELOCITY	25 FT/SEC	NOT REDUCED			
Δax	ACCEL 0.5g(16 ft/sec)	+9 to -11 (100)	-2.5 to 4 (100)	+14 to -14 (100)	+10 to -24 (99)
Δay		+11 to -10 (100)	-2.5 to 3.5(100)	+16 to -15 (98)	+16 to -16 (100)
Δaz		+16 to -12 (100)	-3 to 5.5 (100)	-32 to -25 (20)	+27 to -32 (98)
Δ Accel	28 FT/SEC/SEC	NOT REDUCED			

RUN 1 - STRAIGHT AND LEVEL, 400-500 KTS TAS, 15KFT MSL, DURATION-84 SECONDS, HEADING-347°

RUN 2 - STRAIGHT & LEVEL, 400-500 KTS TAS, 10KFT MSL, DURATION-92 SECONDS, HEADING-257°

4. RMS-II ACCURACY TEST SUMMARY

RUN 3 WAS ANOTHER STRAIGHT AND LEVEL RUN. IT DIFFERED FROM RUN 1 IN THAT THE AIRCRAFT WAS FLYING VERY SLOWLY AROUND 200 KNOTS TRUE AIR SPEED. IN RUN 3, THE POSITION DATA DID NOT MEET SPECIFICATION ON THE ORIGINAL PROCESS AND WERE IMPROVED SOMEWHAT IN THE REVISED DATA. THE VELOCITY WAS BELOW SPECIFICATION IN THE ORIGINAL RUN AND WAS IMPROVED IN THE REPROCESSED DATA. BOTH THE ORIGINAL AND REVISED DATA ON RUN 3 SHOWED GOOD AGREEMENT WITH THE RMS-II AND THE THEODOLITE DATA. THIS AGAIN WAS A STRAIGHT AND LEVEL FLIGHT WITH ESSENTIALLY ZERO ACCELERATION, AND ONE WOULD BE EXTREMELY DISTURBED TO FIND LARGE DIFFERENCES BETWEEN THE RMS-II AND THEODOLITE ESTIMATES OF THE TIME/POSITION DERIVATIVES.

RUN 4 WAS AN ANIMAL OF A DIFFERENT COLOR. THE AIRCRAFT WAS CAUSED TO PORPOISE AT LOW LEVEL IN ORDER TO GET AN ESTIMATE BETWEEN THE TWO SYSTEMS WHEN THE TARGET WAS MANEUVERING. IT IS INTERESTING AGAIN TO NOTE THAT THE RMS-II DID NOT EVER MEET THE POSITION STATED CAPABILITY IN THE ORIGINAL OR REVISED POST-FLIGHT PROCESS AND SHOWED ALMOST NO IMPROVEMENT BETWEEN THE TWO PROCESSES. SO FAR AS VELOCITY WAS CONCERNED, THE DIFFERENCE BETWEEN THE TWO SHOWED VERY LARGE DEVIATION AND WAS NOT CONSIDERED WITHIN STATED CAPABILITY. THE AGREEMENT BETWEEN THE TWO WAS 65% OF THE TIME WITHIN THE STATED SPECIFICATION OF THE 1/2G UNCERTAINTY.

RMS-II ACCURACY TEST SUMMARY

PAR EVAL	RMS-II STATED CAPABILITY	RUN 3 ORIGINAL	%	RUN 3 REVISED	%	RUN 4 ORIGINAL	%	RUN 4 REVISED	%
Δx		+30 to -30	(95)	+24 to -26	(99)	+17 to -58	(40)	+7 to -45	(76)
ΔY	25 FT (1σ)	-28 to +9	(99)	+14 to -12	(100)	+30 to -52	(85)	+37 to -37	(96)
Δz		-75 to +102	(40)	-105 to +50	(40)	+730 to -1100	(1)	+730 to -400	(32)
Δ POSITION	43 FT (1σ)	10 to 130	(40)	105 to 7	(55)	50 to 1100	(1)	730 to 20	(12)
Δvx		+28 to -23	(95)	+17 to -10	(100)	-25 to +22	(94)	+12 to -17	(99)
Δvy	15 FT/SEC	+16 to -20	(99)	+9 to -7.5	(100)	+28 to -30	(94)	+18 to -28	(93)
Δvz		-48 to +70	(25)	-30 to +40	(93)	-210 to +240	(14)	-90 to +100	(12)
Δ VELOCITY	25 FT/SEC	NOT REDUCED							
Δax		+16 to -13	(100)	+6.2 to -3.4	(100)	+13 to -13	(100)	+6.5 to -9.5	(100)
Δay	ACCEL	+14 to -11	(100)	+3.8 to -2.8	(100)	-21 to +19	(98)	-8.5 to 7.5	(100)
Δaz	0.5g (16FT/SEC/SEC)	+23 to -18	(98)	+7.5 to -6	(100)	-60 to +53	(65)	-34 to +33	(65)
Δ ACCEL	28FT/SEC/SEC	NOT REDUCED							

RUN 3 - STRAIGHT AND LEVEL, 200 KTS TAS, 15KFT MSL, DURATION-156 SECONDS, HEADING-347°

RUN 4 - PORPOISE, 400-500 KTS TAS, 300-500 FT AGL, DURATION-68.9 SECONDS, HEADING-347°

5. RMS-II ACCURACY TEST SUMMARY (RUN 5)

RUN 5 SHOWED EXTREMELY LARGE DEVIATIONS IN POSITION, VELOCITY AND ACCELERATION. RUN 5 WAS A WEAPONS DELIVERY MANEUVER IN WHICH THE AIRCRAFT STARTED AT 10,000 FEET ABOVE THE GROUND, DOVE TO 4500 FEET, RELEASED A SIMULATED WEAPON, RECOVERED AT 1000 FEET ABOVE THE GROUND, AND THEN PULLED UP AND CLIMBED OUT TO THE END OF THE MANEUVER. THE RUN WAS BROKEN UP INTO TWO PARTS, THE DIVE AND THE CLIMB, MAINLY FOR DATA REDUCTION SIMPLIFICATION. IN THE DIVE, THE SYSTEM DID NOT MEET SPECIFICATIONS EVEN AFTER THE REVISED DATA PROCESSING AND IN THE CASE OF ACCELERATION WAS MADE SIGNIFICANTLY WORSE BY THE SECOND PROCESS. ON THE CLIMB-OUT PART OF THE RUN, THE DEVIATIONS WERE SO LARGE, PARTICULARLY IN POSITION, THAT ONE COULD CONCLUDE THAT EITHER THE RMS-II WAS BROKEN OR THE SYSTEM SIMPLY CANNOT HANDLE TARGET MANEUVERS. DEVIATIONS ABOVE THE 11,000 FT WERE NOTED IN THE POSITION VECTOR COLUMN WHICH WERE REDUCED TO 2400 FT DEVIATIONS ON THE POST-FLIGHT PROCESS. ON THE WHOLE, ALL OF THE DATA DEVIATED FROM THE THEODOLITE SOLUTION SUCH THAT NO CREDIBLE PERCENT OF TIME WITHIN SPECIFICATION COULD BE ASSIGNED.

RMS-II ACCURACY TEST SUMMARY

RUN 5

PAR EVAL	RMS-II STATED CAPABILITY	ORIGINAL DIVE %	DIVE REVISED %	ORIGINAL CLIMB %	CLIMB REVISED %
Δx		+13 to -55 (80)	-10 to -100 (41)	+400 to -2600 (70)	-240 to -200 (38)
ΔY	25 FT (1σ)	+8 to -34 (95)	+3 to -52 (90)	+320 to -350 (70)	-300 to +150 (50)
Δz		-25 to +550 (30)	-375 to +260 (20)	-2500 to +11000 (?)	2400 to +2500 (?)
Δ POS	43 FT (1σ)	25 to 550 (31)	20 to 360 (27)	0 to 11000 (?)	0 to 2400 (?)
Δvx		+23 to -28 (91)	+18 to -48 (90)	+225 to -750 (?)	-200 to +110 (?)
Δvy	15 FT/SEC	+25 to -25 (91)	+26 to -23 (93)	+260 to -120 (?)	-240 to +85 (?)
Δvz		-75 to +105 (40)	+130 to -130 (15)	+2600 to 1100 (?)	-1300 to +900 (?)
Δ VEL	25 FT/SEC	NOT REDUCED			
Δax		+17 to -14 (100)	+14 to -15 (100)	-225 to +250 (?)	-120 to +80 (?)
Δay	ACCEL	+18 to -15 (99)	+14 to -10 (100)	-100 to +550 (?)	-220 to +85 (?)
Δaz	0.5g (16 FT/SEC/SEC)	-35 to -35 (77)	+40 to -45 (44)	-350 to +450 (?)	-250 to +380 (?)
Δ ACCEL	28 FT/SEC/SEC	NOT REDUCED			

WEAPON DELIVERY MANEUVER. 400-500 KTS TAS. START AT 10KFT AGL AT 302°, RIGHT BANK TO 347°, DIVE AT 21°, WEAPON RELEASE AT 4500 AGL, RECOVER AT 1000 FT AGL; PULL UP OF 30°, ROLL LEFT AND CLIMB 5° ON HEADING OF 270°; DURATION - 118.5 SECONDS.

6. RMS-II ACCURACY TEST SUMMARY (RUN 6/6A)

FOR THE SIXTH RUN, THE CHART IS LABELED 6A. THE DATA FROM RUN 6 WERE NOT USED BECAUSE THE RMS-II OPERATING PERSONNEL ANNOUNCED THAT THE SYSTEM WAS NOT OPERATING AND THE OPERATION WAS RUN LATER AS 6A.

THIS RUN WAS A FAST CLIMB, STARTING AT 5000 FT ABOVE THE GROUND AND CLIMBING TO 25,000 FT ABOVE THE GROUND. HERE THE POSITION SPECIFICATION WAS MET 63% OF THE TIME ON THE ORIGINAL RUN BUT WAS REDUCED TO MEETING SPECIFICATIONS LESS THAN 42% OF THE TIME ON REPROCESSING. THE VELOCITY ESTIMATE WAS REDUCED FROM 67% TO 30% ON REPROCESSING AND ACCELERATION ESTIMATES IN THE Z COORDINATES WERE REDUCED FROM 75% TO 52%, INDICATING THAT THE COMPUTATION HAD NO EXTERNAL MEANS OF TELLING WHETHER THE SYSTEM WAS IMPROVING OR NOT.

RMS-II ACCURACY TEST SUMMARY

RUN 6A

PAR EVAL	RMS-II MEAS CAPABILITY	ORIGINAL	%	REVISED	%
Δx		+10 to -60	(80)	+4 to -100	(70)
ΔY	25 FT (1σ)	-23 to +20	(100)	+25 to -15	(100)
Δz		-30 to +158	(30)	-100 to +185	(33)
Δ POSITION	43 FT (1σ)	5-170	(63)	10 to 210	(42)
Δvx		-37 to +28	(87)	+18 to -33	(88)
Δvy	15 FT/SEC	-25 to +28	(91)	+18 to -30	(94)
Δvz		-70 to +82	(67)	-120 to +170	(30)
Δ VELOCITY	25 FT/SEC	NOT REDUCED			
Δax		+9 to -18	(98)	+6.5 to -9	(100)
Δay	ACCEL	+17 to -23	(95)	+15 to -25	(91)
Δaz	0.5g(16 FT/Sec/Sec	-55 to +55	(75)	-60 to +60	(52)
Δ Accel	28 FT/SEC/SEC	NOT REDUCED			

FAST CLIMB; 550-600 KTS TAS START 10KFT MSL;CLIMB TO 30 KFT MSL; DURATION - 58 SECONDS,

HEADING - 347°

7. RMS-II TEST SUMMARY

THE SUMMARY OF THIS TEST INDICATES AT LEAST TWO THINGS:

THE RMS CALIBRATION IS QUESTIONABLE, AND

THE RMS-II DOES NOT APPEAR CAPABLE OF PRODUCING AIRCRAFT TRAJECTORIES DURING MANEUVERS, MUCH LESS PRODUCE ACCURATE TRAJECTORIES.

RMS-II TEST SUMMARY

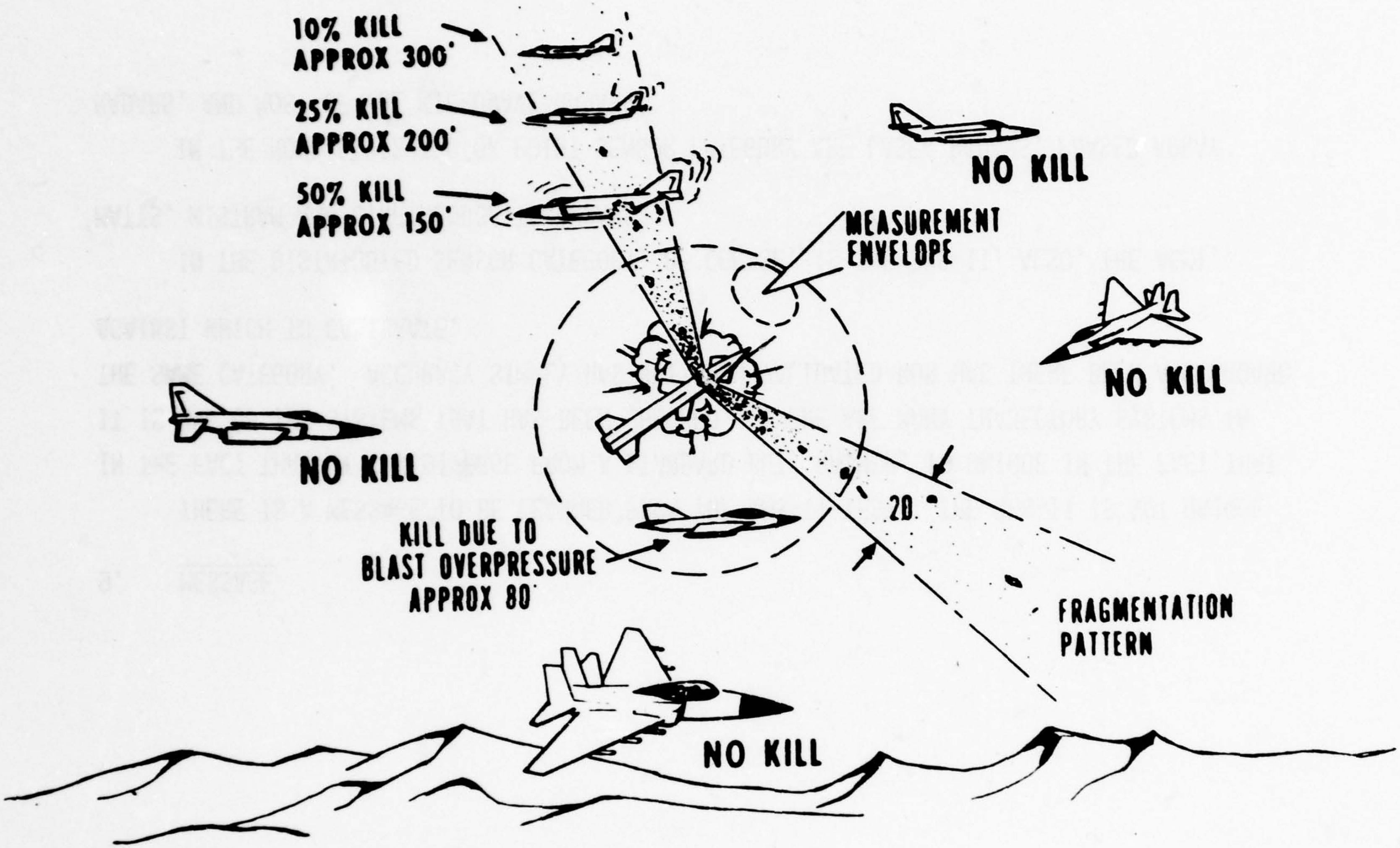
-- CALIBRATION OF RMS-II IS QUESTIONABLE.

-- RMS-II DOES NOT APPEAR CAPABLE OF PRODUCING AIRCRAFT TRAJECTORIES DURING MANEUVERS.

8. LETHALITY MEASUREMENT ENVELOPE

THIS SLIDE SHOWS THE KINDS OF ACCURACY WE NEED TO SCORE A SIMULATED SA2 LAUNCH. THE MISSILE HAS A BLAST SPHERE OF APPROXIMATELY 80 FEET WITH A TWO-SECTOR PATTERN EXTENDING OUT BEYOND THE OVERPRESSURE SPHERE. IF ONE WERE TO ACTUALLY SCORE, THE ACCURACY OF THE MEASURING EQUIPMENT SHOULD BE IN THE ORDER OF 10 TIMES BETTER THAN THE SIMULATED BURST ENVELOPE. THIS REQUIRES AN ACCURACY OF APPROXIMATELY 10 FEET. AS YOU CAN PLAINLY SEE, THE RMS-II NEVER CAME CLOSE TO THIS NOR WAS IT ADVERTISED TO BE 10 FEET. IT WAS ADVERTISED TO BE APPROXIMATELY 45 FEET BUT THAT NUMBER WAS RARELY MET, PARTICULARLY IN THE MANEUVERING CASE.

LETHALITY MEASUREMENT ENVELOPE



9. MESSAGE

THERE IS A MESSAGE TO BE LEARNED FROM THE RMS-II TEST. THE RMS-II IS NOT UNIQUE IN THE FACT THAT IT CAN DIVERGE FROM A STANDARD BUT, RATHER, IS UNIQUE IN THE FACT THAT IT IS ONE OF THE SYSTEMS THAT HAS BEEN CHECKED. THERE ARE MANY TRAJECTORY SYSTEMS IN THE SAME CATEGORY. ACCURACY SIMPLY HAS NOT BEEN VALIDATED NOR HAS THERE BEEN A STANDARD AGAINST WHICH TO CALIBRATE.

IN THE DISTRIBUTED SENSOR CATEGORY, OF COURSE, IS THE RMS-II; ALSO, THE ACMI, MATTS, MISTRAM AND CINETHEODOLITE ARRAYS.

IN THE NONDISTRIBUTED OR POINT SENSOR CATEGORY ARE LASER RADARS, PHASED ARRAY RADARS, AND MOST OF THE MICROWAVE RADARS.

MESSAGE

THERE IS A MESSAGE TO BE LEARNED FROM THE RMS-II TEST.

THERE ARE MANY TRAJECTORY DETERMINING SYSTEMS IN THIS SAME CATEGORY.
ACCURACY HAS <u>NOT</u> BEEN ADEQUATELY VERIFIED.

DISTRIBUTED SENSORS

RMS-II	CINETHEODOLITE ARRAYS
ACMI	
MATTS	
MISTRAM	

NONDISTRIBUTED SENSORS

LASER RADARS	MICROWAVE RADARS
PHASED ARRAY RADARS	

10. <u>VERIFICATION</u>

HERE, THE QUESTION RAISED IS, "WHY HAVE THESE SYSTEMS NOT BEEN VERIFIED AND CALIBRATED?" THE ANSWER IS SIMPLY THAT ADEQUATE STANDARDS HAVE NOT BEEN AVAILABLE. A STANDARD AGAINST WHICH ONE WILL CALIBRATE AND VALIDATE SHOULD SUPPLY THE TOTAL TRAJECTORY DESCRIBED IN TPVA. IT MUST DO THIS ON-LINE, WITHOUT THE NEED OF ANY POST-FLIGHT TRAJECTORY CORRECTION, AND THE SYSTEM BEING USED AS THE STANDARD MUST HAVE DEMONSTRATED MORE ACCURACY THAN THE SYSTEM UNDER TEST. AT THIS POINT, I WOULD LIKE TO REEMPHASIZE THE WORD <u>DEMONSTRATE</u>.

VERIFICATION

WHY NOT ADEQUATE VERIFICATION?

BECAUSE ADEQUATE STANDARDS HAVE <u>NOT</u> BEEN AVAILABLE.

STANDARDS SHOULD:

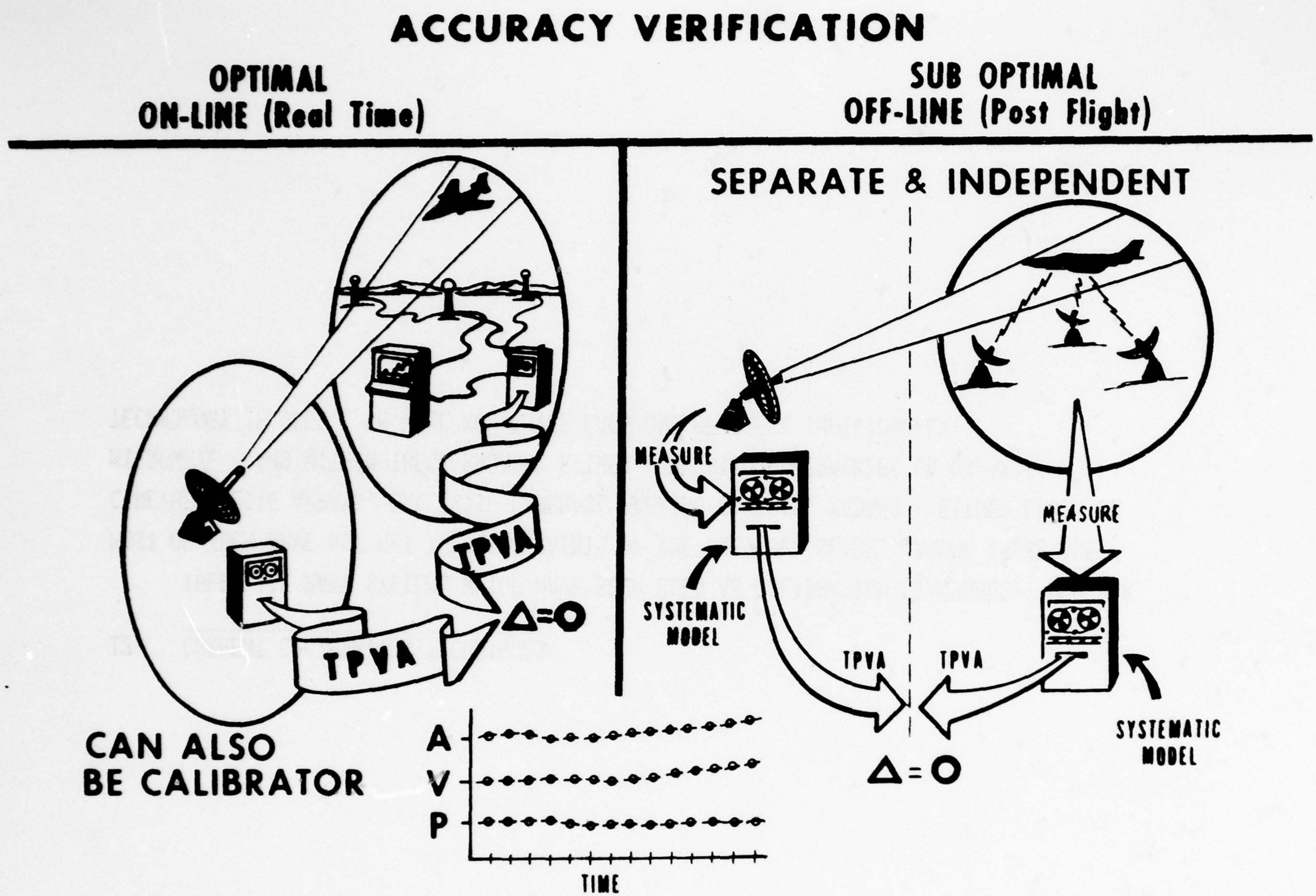
SUPPLY COMPLETE TRAJECTORY TPVA

BE <u>ON-LINE</u> TO ALLOW VERIFICATION AND CALIBRATION

<u>DEMONSTRATE</u> MORE ACCURACY THAN SYSTEM UNDER TEST

11. ACCURACY VERIFICATION

AGAIN, WE WOULD LIKE TO EMPHASIZE THAT ACCURACY SHOULD BE DEMONSTRATED ON-LINE (REAL TIME) WHEREIN THE TOTAL TRAJECTORY IS COMPARED AS IT IS PRODUCED. THIS OF COURSE ONLY APPLIES TO THOSE WHICH PRODUCE A TRAJECTORY (TPVA) ON-LINE. THERE ARE MANY SYSTEMS WHICH DO NOT PRODUCE ON-LINE TRAJECTORIES BUT RATHER REQUIRE POST-FLIGHT PROCESSING, AND THESE MUST BE CHECKED OFF-LINE. IN EITHER CASE, IT IS EXTREMELY IMPORTANT THAT THE DATA UNDER TEST NOT BE AVAILABLE TO THE ORGANIZATIONS WHICH ARE DERIVING THE POST-FLIGHT TRAJECTORY. THIS SEPARATION OF DATA UNTIL A TPVA COMPARISON IS MADE, BOTH THE STANDARD AND THE SYSTEM BEING EVALUATED, IS VERY FREQUENTLY VIOLATED WHEREIN BOTH SYSTEMS ARE "ADJUSTED" UNTIL THEY AGREE. FOR EXAMPLE, IN THE CASE OF AN OFF-LINE PROCESS, THERE ARE SEPARATE INPUTS ASIDE FROM THE MEASUREMENT DATA IN THE FORM OF THE SYSTEMATIC ERROR MODEL. SINCE THE ERROR MODEL CAN CHANGE, ONE MAY ADJUST THE DATA UNTIL THEY AGREE. THERE ARE MANY OTHER WAYS OF MAKING THESE AGREE. TOTAL SEPARATION OF THE SYSTEMS IS MANDATORY.


ACCURACY VERIFICATION
OPTIMAL
ON-LINE (Real Time)
SUB OPTIMAL
OFF-LINE (Post Flight)
SEPARATE & INDEPENDENT
TPVA
TPVA
Δ=O
CAN ALSO
BE CALIBRATOR
A
V
P
TIME
MEASURE
SYSTEMATIC
MODEL
TPVA
TPVA
MEASURE
SYSTEMATIC
MODEL
Δ=O

12. <u>CURRENT CALIBRATION TECHNIQUES</u>

THERE ARE MANY SYSTEMS WHICH HAVE BEEN USED AS CALIBRATION STANDARDS; HOWEVER, MOST OF THEM HAVE NOT MET THE CONSTRAINTS OF THE PREVIOUS SLIDE. AMONG THESE ARE CINETHEODOLITE ARRAYS, BALLISTIC CAMERAS, MAPPING CAMERAS, RADARS - EITHER LASER OR MICROWAVE - AND WITHIN THESE RADARS, EITHER CONVENTIONAL TRACKERS OR ON-AXIS TECHNOLOGY IS USED. WE WILL NOW COVER EACH ONE OF THESE INDIVIDUALLY.

CURRENT CALIBRATION TECHNIQUES

CURRENT TECHNIQUES USED FOR ACCURACY VERIFICATION AND CALIBRATION

- CINETHEODOLITE ARRAYS
- BALLISTIC CAMERAS
- MAPPING CAMERAS
- RADARS - LASER OR MICROWAVE
    - CONVENTIONAL
    - ON-AXIS (ILIC)

13. CINETHEODOLITE ARRAYS

A CINETHEODOLITE ARRAY IS THE SERIES OF INSTRUMENTS MOST OFTEN USED AS STANDARDS AGAINST WHICH TO CHECK OTHER SYSTEMS; HOWEVER, IN MOST CASES THESE SYSTEMS ARE FIXED, ALTHOUGH MOST RANGES DO IN FACT HAVE ONE OR MORE MOBILE CINETHEODOLITES FOR USE AT REMOTE LOCATIONS. THE CINETHEODOLITE SYSTEMS ARE DISTRIBUTED SENSORS WHICH MEANS THEY MUST CALCULATE POSITION WITH THE CONCERN FOR NONORTHOGONALITY, GDOP, DISTRIBUTED TIMING, AS WELL AS THE NOISE OF EACH SENSOR. ALMOST WITHOUT EXCEPTION, CINETHEODOLITES HAVE NOT HAD THEIR ACCURACY VERIFIED EXCEPT BY POST-FLIGHT PROCESSING, WHICH DOES NOT MEET THE CRITERIA FOR A STANDARD. CINETHEODOLITES WHICH PURPORT TO BE ON-LINE DO NOT IN FACT COMPUTE THE TOTAL TRAJECTORY (TPVA) AS IS REQUIRED. MANY OF THE COMPUTATIONS WILL REQUIRE WEEKS OF PROCESSING BEFORE COMPLETE ANSWERS ARE ATTAINED, BUT BY FAR THE LARGEST CONSTRAINT AGAINST THIS SYSTEM IS THAT IT IS NOT WELL ADAPTED AS A MATHEMATICAL STANDARD AGAINST MANEUVERING TARGETS. SINCE THE TOTAL TRAJECTORY, INCLUDING POSITION, MUST BE DETERMINED BY COMPUTATION, THERE IS NO OBSERVABILITY IN THE PROCESS AFTER THE DATA COLLECTION USING THE CINETHEODOLITE ITSELF, ALLOWING THE SYSTEM TO DIVERGE WITHOUT KNOWLEDGE. IT CAN BE USED TO VERIFY A SYSTEM'S TRACKING ACCURACY BUT IS NOT WELL ADAPTED TO THE CALIBRATION PROCESS WHICH IS REQUIRED. CINETHEODOLITES HAVE BEEN USED IN ATTEMPTS TO CALIBRATE OTHER SYSTEMS, HOWEVER, BECAUSE OF THE CONSTRAINTS MENTIONED ABOVE, ARE NOT CONSIDERED ADEQUATE OR ACCURATE CALIBRATION STANDARDS.

CINETHEODOLITE ARRAYS

DISTRIBUTED SENSORS - MUST CALCULATE POSITION

ACCURACY NOT VERIFIED

GENERALLY NOT ON LINE

TRAJECTORY BY COMPUTATION (WEEKS)

NOT WELL ADAPTED TO HIGHLY MANEUVERING TARGETS

NO OBSERVABILITY IN THE DATA PROCESSING

CAN BE USED TO VERIFY A TRACKING SYSTEM'S ACCURACY, BUT NOT TO CALIBRATE

14. BALLISTIC OR MAPPING CAMERA

THE BALLISTIC CAMERA AND THE MAPPING CAMERA WILL BE COMBINED INTO ONE SLIDE. ALTHOUGH THE BALLISTIC CAMERA HAS WIDE USE AND ADAPTABILITY TO SPACE (FREE-FALL PROJECTS), BOTH OF THESE SYSTEMS HAVE LIMITED APPLICATION WHEREIN MANEUVERING TRAJECTORIES ARE INVOLVED. WE HAVE FOUND NO CASE WHERE THESE TECHNIQUES HAVE BEEN VALIDATED FOR MANEUVERING TRAJECTORY PRODUCTION. THIS PROCESS HAS EXTREMELY LIMITED RESOLUTION IN THE UP/DOWN DIRECTION; ALTHOUGH THE MAPPING CAMERA IS EXTREMELY USEFUL TO DETERMINE THE SEPARATION AND/OR LOCATION OF GROUND OBJECTS IT IS NOT A STRONG CANDIDATE TO DETERMINE WHERE THE AIRCRAFT IS LOCATED IN THREE ORTHOGONAL DIMENSIONS. THE EXTREMELY SMALL NUMBER OF DATA PROCESSING POINTS PRODUCED WITH EITHER ONE OF THESE SYSTEMS MAKES IT IMPRACTICAL TO COMPUTE THE VELOCITY AND ACCELERATION WHICH IS SO NEEDED IN THE TPVA DESCRIPTION.

BALLISTIC OR MAPPING CAMERA

NON-REAL TIME (WEEKS TO MONTHS DELAY)

INFREQUENTLY VERIFIED

VERY LIMITED $\not{Z}$ RESOLUTION

IMPRACTICAL TO COMPUTE VELOCITY AND ACCELERATION

15. DERIVATIVE TRACKING RADARS (CONVENTIONAL)

THERE ARE MANY TRACKING RADARS AT ALL PARTS OF THE SPECTRUM, INCLUDING OPTICAL. THEY ARE FREQUENTLY ON-LINE, HOWEVER; DATA ARE CORRECTED OUTSIDE OF THE TRACKING LOOPS AND THIS GENERALLY GIVES ACCURACY WHICH IS NOT ADEQUATE TO THE NEED. THEY DO NOT PRODUCE THE TOTAL TRAJECTORY ON-LINE BUT RATHER A TIME SEQUENCE OF POSITION. SINCE THE DERIVATIVES MUST BE PRODUCED FROM THE TIME-POSITION DATA THEY CAN AT BEST BE AVERAGES WHEREIN INSTANTANEOUS VALUES ARE NEEDED FOR MANEUVERING TRAJECTORIES. THE CALIBRATION OF THESE CONVENTIONAL RADARS IS FUNCTIONALLY INADEQUATE IN THAT THE CORRECTION ROUTINES ARE MATHEMATICAL IN NATURE AND PHYSICALLY DIVERGE FROM THE PHYSICAL MODELS WHICH ARE NEEDED. IN ADDITION, THE DATA PROCESSING IS NOT OBSERVABLE, THUS CAUSING THE FINAL DATA TO DIVERGE IN SOME CASES. IT DOES HAVE A STRONG POINT IN THAT FREQUENTLY THESE SYSTEMS ARE TRANSPORTABLE.

DERIVATIVE TRACKING RADARS
(CONVENTIONAL)

LASER OR MICROWAVE

CAN BE ON LINE

ACCURACY GENERALLY NOT ADEQUATE

PRODUCES AVERAGE VALUES FOR TIME-POSITION DERIVATIVES

CALIBRATION FUNCTIONALLY INADEQUATE

DATA PROCESSING NOT OBSERVABLE

CAN BE TRANSPORTABLE

16. IN-LOOP/INTEGRATION CONTROL RADAR

THERE IS A CLASS OF TRACKING INSTRUMENTS WHICH IS KNOWN AS IN-LOOP INTEGRATION CONTROL (ILIC) SYSTEMS. THIS TECHNOLOGY CAN APPLY TO ANY TYPE OF TRACKER; HOWEVER, A SPECIAL SUBSET OF ILIC SYSTEMS, KNOWN AS ON-AXIS, APPLIES TO INSTRUMENT SENSORS WHICH ARE POINTED DIRECTLY AT THE TARGET AND ARE KNOWN AS ON-AXIS MICROWAVE OR LASER RADARS. THE ON-AXIS RADAR USES VERY HIGHLY REFINED CALIBRATION PROCEDURES, ENABLING THE SYSTEM TO BE CALIBRATED TO THE PRECISION OF THE ENCODERS. THE SYSTEM ALLOWS THE DIRECT OBSERVATION OF EACH TERM IN THE SYSTEMATIC ERROR MODEL. IT USES STARS AS AN ABSOLUTE POSITION REFERENCE AND EMPLOYS OBSERVATIONS AGAINST DYNAMIC TARGETS TO INSURE THAT THE SENSOR IS ALWAYS POINTED DIRECTLY AT THE TARGET. IT IS THIS POINTING TECHNIQUE THAT ALLOWS THE RESULTS OF DATA PROCESSING TO BE OBSERVABLE AT ALL TIMES. THE ILIC SYSTEM PRODUCES A TOTAL TRAJECTORY ON-LINE (REAL TIME) TO ACCURACIES BETTER THAN NEEDED FOR MOST OF THE CALIBRATION/VALIDATION INSTRUMENTS. THE ACCURACY OF THE ON-AXIS SYSTEMS IS DEMONSTRATED BY DRIVING ONE SYSTEM WITH ANOTHER AFTER EACH OF THE SYSTEMS HAS BEEN INDEPENDENTLY CALIBRATED. THESE SYSTEMS MAY BE TRANSPORTABLE, ALTHOUGH TODAY ONLY OPTICAL VERSIONS ARE TRANSPORTABLE. ABOVE ALL, IT CAN ESTABLISH ACCURATE TRAJECTORIES ON MANEUVERING TARGETS.

IN-LOOP/INTEGRATION CONTROL RADAR

- LASER OR MICROWAVE (ON-AXIS)
- HIGHLY REFINED CALIBRATION PROCEDURES
  - ERROR REMOVAL IS OBSERVABLE
  - USES STARS FOR ABSOLUTE REFERENCE
  - RESULTS OF DATA PROCESSING OBSERVABLE
- PROVIDES TOTAL TRAJECTORY ON-LINE
- ACCURACY BETTER THAN SYSTEMS TO BE TESTED - DEMONSTRATED BY DRIVING ONE SYSTEM WITH ANOTHER
- MAY BE TRANSPORTABLE
- CAN ESTABLISH ACCURATE TRAJECTORY ON A MANEUVERING TARGET

17. TIME, POSITION, VELOCITY AND ACCELERATION (TPVA)

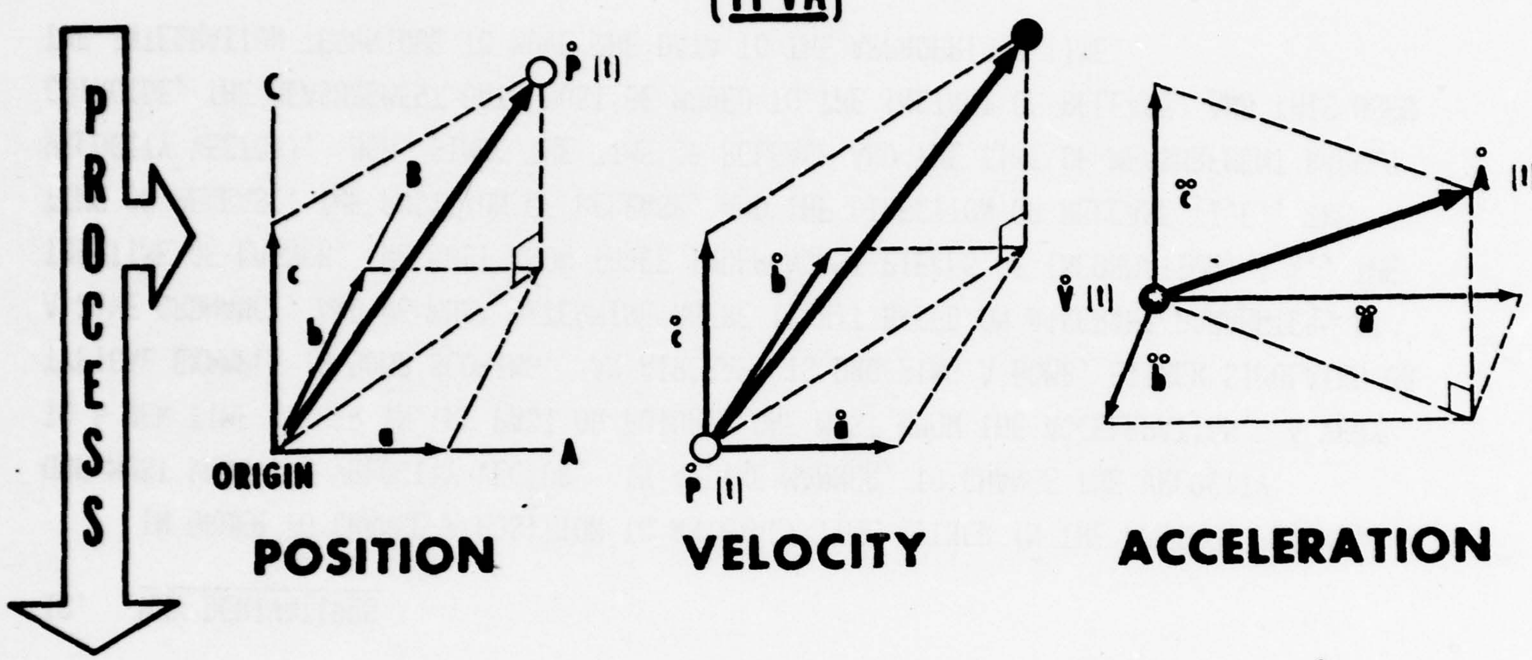
ON THE NEXT TWO SLIDES, WE SHOULD LIKE TO TALK ABOUT WHAT THE PROBLEM REALLY IS. WHAT IS PRODUCED IS A VECTORIAL DESCRIPTION OF THE DYNAMICS OF THE TARGET, KNOWN AS TPVA. IT IS MADE UP OF TIME (T), POSITION (P), VELOCITY (V) AND ACCELERATION (A). NOTICE THE GRAPHICS SHOW POSITION OF THE TARGET AS DEFINED FROM SOME ORIGIN AND IS DESCRIBED IN ORIENTATION BY THREE VECTORIAL COMPONENTS WHICH MUST BE ORTHOGONAL AND ARE CALLED A, B, AND C. VELOCITY AND ACCELERATION ARE DESCRIBED IN LIKE MANNER.

THERE ARE TWO PROCESSES BY WHICH ONE MAY COMPUTE THE TIME-POSITION DERIVATIVES. THE FIRST IS BY DIFFERENTIATION TO DISCOVER THE CHANGE OF POSITION AS A FUNCTION OF TIME AND PROCESSED TO DISCOVER THE CHANGE OF VELOCITY AS A FUNCTION OF TIME.

THE SECOND METHOD IS BY INTEGRATION. HERE ONE STARTS WITH AN ESTIMATE OF ACCELERATION OR, IN MANY CASES, HIGHER DERIVATIVES; IN ANY CASE OF ACCELERATION A DOUBLE INTEGRATION IS ACCOMPLISHED TO GIVE THE CHANGE OF POSITION. WHEN THIS IS ADDED TO THE OLD POSITION, ONE HAS A NEW ESTIMATE, P(T). IN A LIKE MANNER, A SINGLE INTEGRATION OF THE ACCELERATION WILL PRODUCE A NEW ESTIMATE OF VELOCITY.

TIME, POSITION, VELOCITY, ACCELERATION

(TPVA)



DIFFERENTATION $\quad P(t) \Rightarrow \frac{dP}{dt} \Rightarrow \frac{dV}{dt}$ OR $\frac{d^2P}{dt^2}$

INTEGRATION $\quad \iint_0^{t_1} A(t)dt = \Delta P + \mathring{P}(t) = P(t) \Leftarrow \int_0^{t_1} A(t)dt = \Delta V + \mathring{V}(t) = V(t_1) \Leftarrow A(t)$

18. WHY DERIVATIVES

IN ORDER TO CHANGE A POSITION TO AN EXACT TIME EITHER IN THE PAST OR FUTURE, ONE MUST KNOW THE VELOCITY VECTOR. IN A LIKE MANNER, TO CHANGE THE VELOCITY TO A NEW TIME EITHER IN THE PAST OR FUTURE, ONE MUST KNOW THE ACCELERATION. A VERY TYPICAL EXAMPLE IS BOMB SCORING. AN AIRCRAFT IS DROPPING A BOMB, EITHER SIMULATED OR A LIVE ORDNANCE, AND WE MUST DETERMINE WHERE IT HIT BASED ON AIRCRAFT PARAMETERS AT THE TIME OF LAUNCH. WE MUST KNOW THREE INDEPENDENT PIECES OF INFORMATION, I.E., THE TIME OF RELEASE, THE POSITION OF RELEASE, AND THE DIRECTION OF RELEASE (I.E., THE VELOCITY VECTOR). NOW, SINCE THE TIME OF RELEASE AND THE TIME OF MEASUREMENT RARELY COINCIDE, THE MEASUREMENT DATA MUST BE MOVED TO THE INSTANT OF RELEASE, AND THIS USES THE INTEGRATION TECHNIQUE TO MOVE THE DATA TO THE APPROPRIATE TIME.

WHY DERIVATIVES ?

- TO UPDATE POSITION TO A NEW EPOCH, ONE MUST KNOW THE VELOCITY VECTOR.
- TO UPDATE VELOCITY TO A NEW EPOCH, ONE MUST KNOW THE ACCELERATION.

Example:

AN AIRCRAFT IS DROPPING A SIMULATED BOMB, AND WE MUST DETERMINE WHERE IT HIT.

- ONE MUST KNOW THE TIME OF RELEASE
- ONE MUST KNOW THE POSITION OF RELEASE
- ONE MUST KNOW THE DIRECTION OF RELEASE
  ie. THE VELOCITY VECTOR.

THE TIME OF RELEASE AND THE TIME OF MEASUREMENT RARELY COINCIDE AND MUST BE MOVED TO THE TIME OF RELEASE.

$$\int_{\text{TIME OF MEASUREMENT}}^{\text{TIME OF RELEASE}} \bar{a} = \bar{V} \text{ AT TIME OF RELEASE}$$

$$\int_{\text{TIME OF MEASUREMENT}}^{\text{TIME OF RELEASE}} \bar{V} = P \text{ AT TIME OF RELEASE}$$

19. TRAJECTORY AT EPOCH

TPVA, WHICH AGAIN IS TIME, POSITION, VELOCITY AND ACCELERATION, DESCRIBES A TRAJECTORY AT A GIVEN TIME OR EPOCH. IF THE TARGET IS NOT MANEUVERING, THEN THE ACCELERATION IS A CONSTANT. IF THE ACCELERATION IS A CONSTANT, THAT MEANS THAT THE VELOCITY IS CHANGING IN A VERY PREDICTABLE WAY AND THE TERMS THAT YOU COMPUTE WILL BE GOOD FOR VERY LONG PERIODS OF TIME; THEREFORE, AN AVERAGING TECHNIQUE WILL PRODUCE ANSWERS WHICH ARE VALID. IF THE TARGET, HOWEVER, IS MANEUVERING, THAT MEANS THAT THE ACCELERATION IS NOT A CONSTANT AND ONE MUST PRODUCE A SERIES OF TPVA IN ORDER TO DESCRIBE THE TRAJECTORY OF THE TARGET. THIS IMPLIES SOMETHING COMPLETELY DIFFERENT, IN THAT THE ACCELERATION IS CHANGING, THEN LONG-TERM AVERAGES DO NOT HOLD ANY LONGER AND ONE MUST COMPUTE DERIVATIVES WHICH APPROACH INSTANTANEOUS VALUES.

GOING TO THE NEXT CHART ON TPVA: ONE GENERALLY USES THE DERIVATIVE PROCESS FOR LONG-TERM AVERAGES; HOWEVER, IF ONE NEEDS INSTANTANEOUS VALUES, THEY GENERALLY ARE PRODUCED BY INTEGRATION, WHEREIN THE TIME INTERVAL OVER WHICH ONE INTEGRATES IS KEPT ARBITRARILY SHORT.

TRAJECTORY AT EPOCH

TPVA - TRAJECTORY AT EPOCH (T)

IF TARGET IS NOT MANEUVERING, THEN $A = K$ AND AVERAGING TECHNIQUES GIVE GOOD RESULTS

IF TARGET IS MANEUVERING, THEN

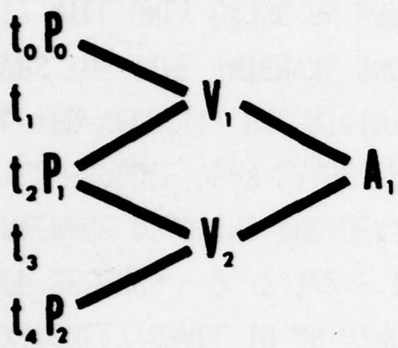
- $A \neq K$
- A SERIES OF TPVA NEEDED
- DERIVATIVES MUST APPROACH INSTANTANEOUS VALUES

20. TPVA

IN THE DIFFERENTIATION PROCESS, A LONG SEQUENCE OF TIME/POSITION MEASUREMENTS ARE NEEDED. THE MORE NOISY THE DATA, THE LONGER THE TIME/POSITION DATA SPAN MUST BE TO GIVE THE AVERAGE VALUES NEEDED. IN PRACTICE, THIS TECHNIQUE (DERIVATIVE) IS VALID ONLY FOR THE NON-MANEUVERING TARGET. IN ADDITION, TIME TAGGING ERRORS OF THE DERIVATIVES MAY BE INTRODUCED. THESE TIME TAGGING ERRORS ARE NOT SIGNIFICANT IF THE TARGET IS NOT MANEUVERING, BUT ARE OF PRIME CONSIDERATION WHEN MANEUVERS TAKE PLACE. THE NUMERICAL TECHNIQUE EMPLOYED IN THE DERIVATIVE PROCESS IS SHOWN AT THE BOTTOM OF THE CHART. THE CONTRA-POSITIVE IS TO USE AN INTEGRATION PROCESS WHEREIN THE INTEGRATION TIME MAY BE KEPT ARBITRARILY SHORT. IN THIS INTEGRATION PROCESS THE COMPUTED POSITION IS COMPARED TO THE MEASURED POSITION AND THE TPVA ADJUSTED UNTIL THE DIFFERENCE IS ZERO.

TPVA

DIFFERENTATION



i.e.

$$\frac{P_1 - P_0}{t_2 - t_0} = (V_1)_1 \quad , \quad \frac{P_2 - P_1}{t_4 - t_2} = (V_2)_3$$

and

$$\frac{(V_2)_3 - (V_1)_1}{t_3 - t_1} = (A_1)_2$$

INTEGRATION

$$\iint_{NOW}^{FUTURE} A_1 = P_F$$

$$P_F - P_M = 0$$

i.e.

$$P_i = P_{i-1} + \Delta t\dot{P} + \frac{(\Delta t)^2}{2}\ddot{P}_i$$

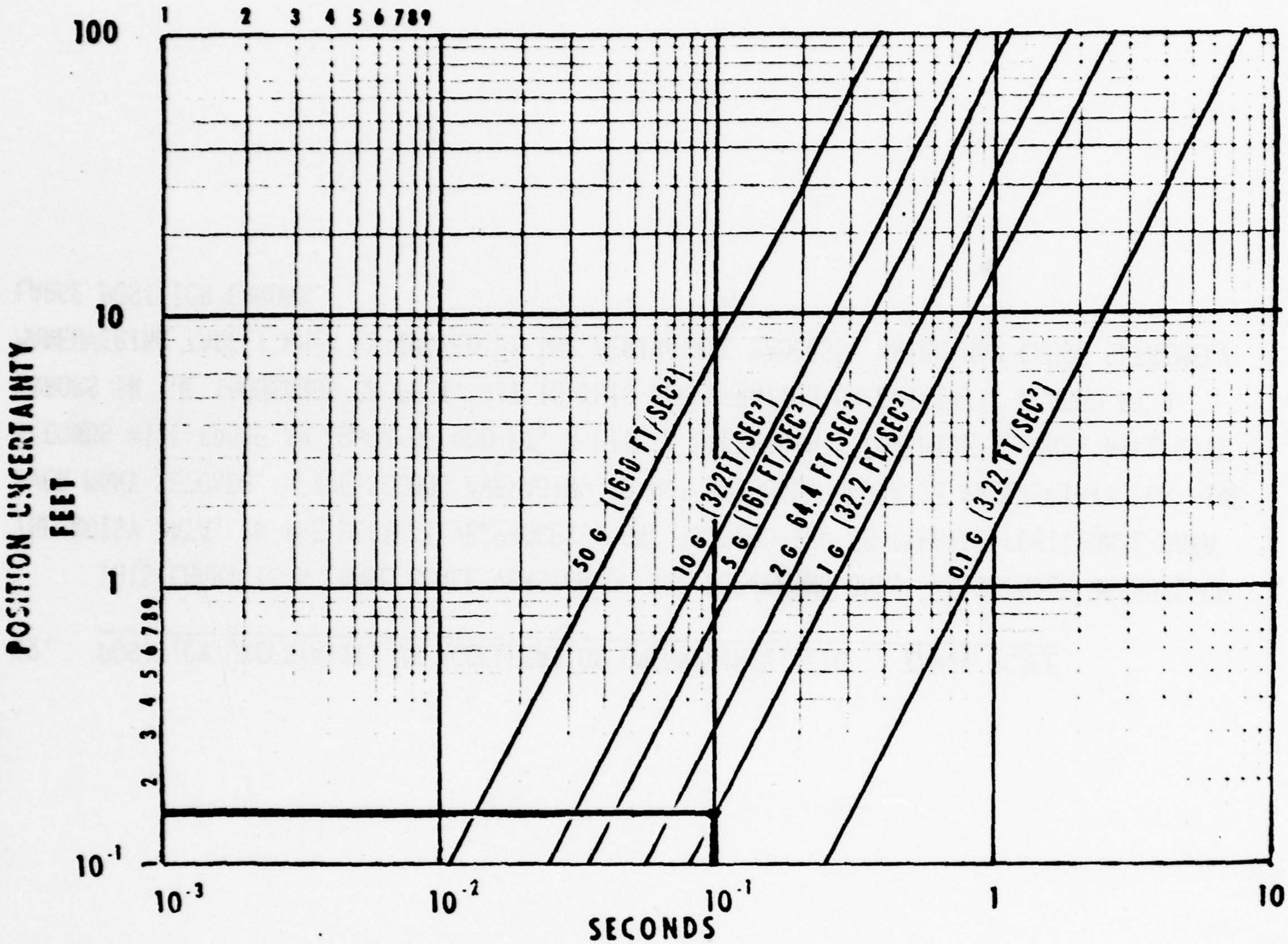
and

$$\dot{P}_i = \dot{P}_{i-1} + \Delta t\ddot{P}_i$$

21. <u>POSITION UNCERTAINTY VS ACCELERATION UNCERTAINTY AS A FUNCTION OF ELAPSED TIME</u>

THIS NEXT CHART, WHICH SHOWS THE EFFECTS OF ACCELERATION UNCERTAINTY ON POSITION, IS OF INTEREST IN THIS DISCUSSION PRIMARILY BECAUSE IT WILL GIVE YOU AN INSIGHT INTO THE MAGNITUDE OF THE ERRORS ONE SEES IN POSITION. ASSUMING A 1G TURN, WHICH AS MOST OF YOU KNOW IS EXTREMELY SMALL IN AN AIRCRAFT, AND IF THERE WERE AN UNCERTAINTY OF THAT 1G FOR A COUPLE OF SECONDS - 2, 2 1/2 - THERE IS A POSITION UNCERTAINTY OF 100 FEET. FREQUENTLY THE TIME AVERAGE OF USING THE DERIVATIVE PROCESS EXTENDS OUT MANY SECONDS AND THIS, IN ITSELF, WILL PRODUCE VERY LARGE ERRORS IN POSITION ASIDE FROM THOSE WHICH MIGHT BE CAUSED BECAUSE OF THE VELOCITY UNCERTAINTY. I SHOULD LIKE TO POINT OUT ALSO ON THIS CHART THAT IF ONE KEEPS THE TIME INTERVAL SHORT, IN THE ORDER OF 1/10 OF A SECOND, THIS SAME 1G UNCERTAINTY WILL ONLY CAUSE AN ERROR OF ABOUT 1/10 OF A FOOT.

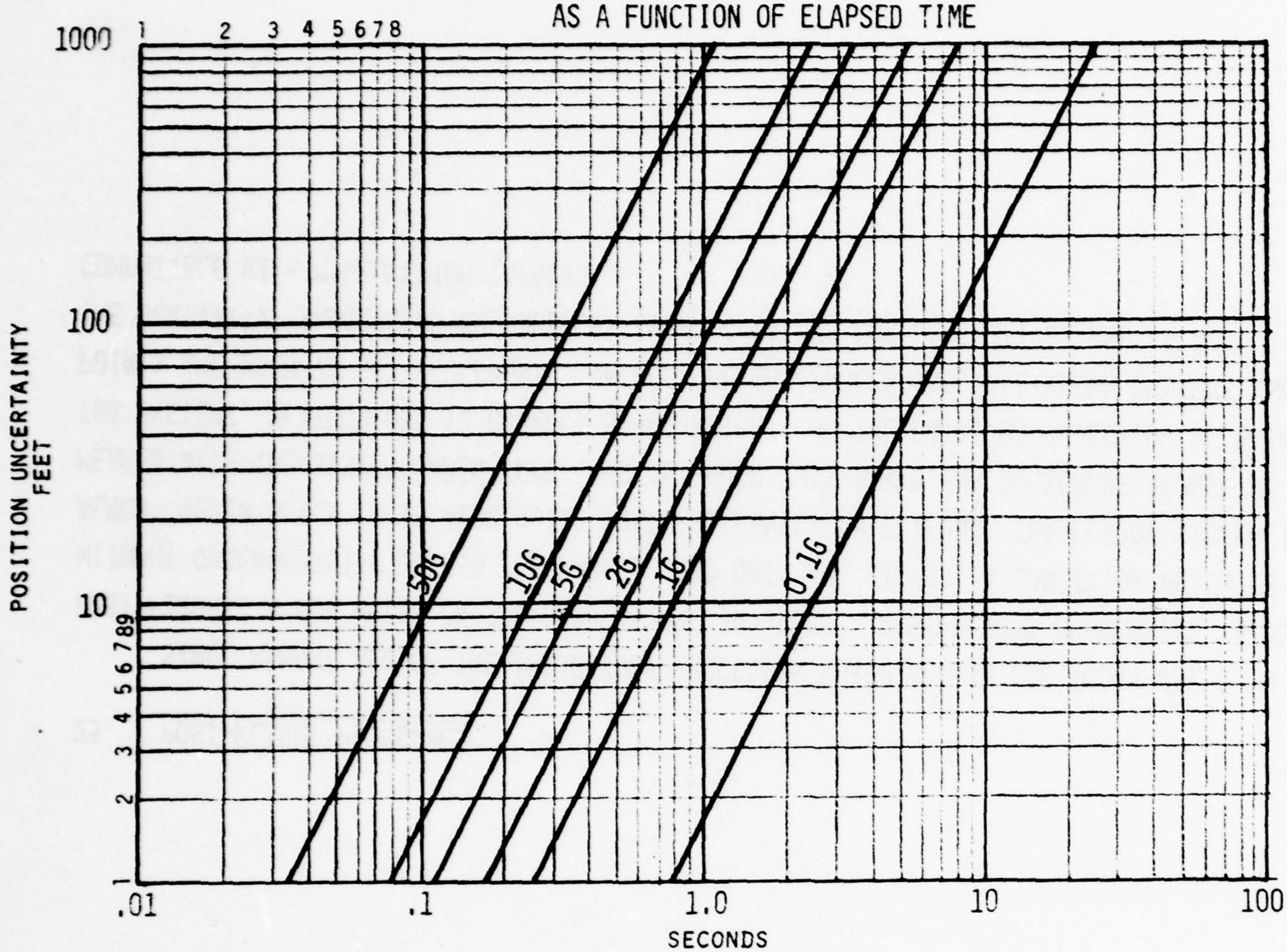
POSITION UNCERTAINTY vs ACCELERATION UNCERTAINTY AS A FUNCTION OF ELAPSED TIME



22. <u>POSITION UNCERTAINTY VS ACCELERATION UNCERTAINTY, ETC. - LARGE SCALE</u>

THIS CHART IS A LARGE SCALE VERSION OF THE PRECEDING ONE. FREQUENTLY BECAUSE OF THE NOISY DATA, IN THE DERIVATIVE PROCESS, ONE IS REQUIRED TO AVERAGE POSITIONAL DATA OVER MANY SECONDS. FIVE-SECOND AVERAGING IS NOT UNUSUAL, AND A 1G UNCERTAINTY FOR FIVE SECONDS WILL CAUSE AN ERROR OF 400 FT, A FIVE G UNCERTAINTY FOR FIVE SECONDS WILL GIVE ERRORS IN THE THOUSANDS OF FEET. IT IS THIS ACCELERATION UNCERTAINTY, CAUSED BY A MANEUVERING TARGET WHEN ESTIMATED BY THE DERIVATIVE PROCESS, WHICH MAY CAUSE EXTREMELY LARGE POSITION ERRORS.

POSITION UNCERTAINTY vs ACCELERATION UNCERTAINTY
AS A FUNCTION OF ELAPSED TIME



23. POST-FLIGHT PROCESSES

SINCE ALMOST ALL OF THE TRAJECTORY PROCESSES WHICH ARE IN USE TODAY USE A POST-FLIGHT, A FEW WORDS ON THE SUBJECT ARE IN ORDER. POST-FLIGHT PROCESSING IS DONE WITHOUT OBSERVABILITY UNLESS THE PROCESS AND DATA ARE LINEAR, A CONDITION WHICH IS ALMOST NEVER MET. IT IS ALSO NOTED THAT FREQUENTLY AN EXTERNAL TRAJECTORY SYSTEM IS MERGED WITH THE SYSTEM UNDER TEST, AND ALTHOUGH THIS MAKES FOR AGREEMENT AMONG THE TWO SYSTEMS, NEITHER ONE IS CORRECT SINCE WEIGHTS OF THE DATA, OR REJECTION OF DATA POINTS ARE USED TO GET AGREEMENT. IN POST-FLIGHT PROCESSING, ALL KNOWN SYSTEMS USE THE DERIVATIVE PROCESS WHICH PRODUCES AVERAGE VALUES FOR DERIVATIVES AND IS NOT COMPATIBLE WITH MANEUVERING TARGETS.

POST-FLIGHT PROCESSES

-- NOT VALID WITHOUT OBSERVABILITY (EXTERNAL)

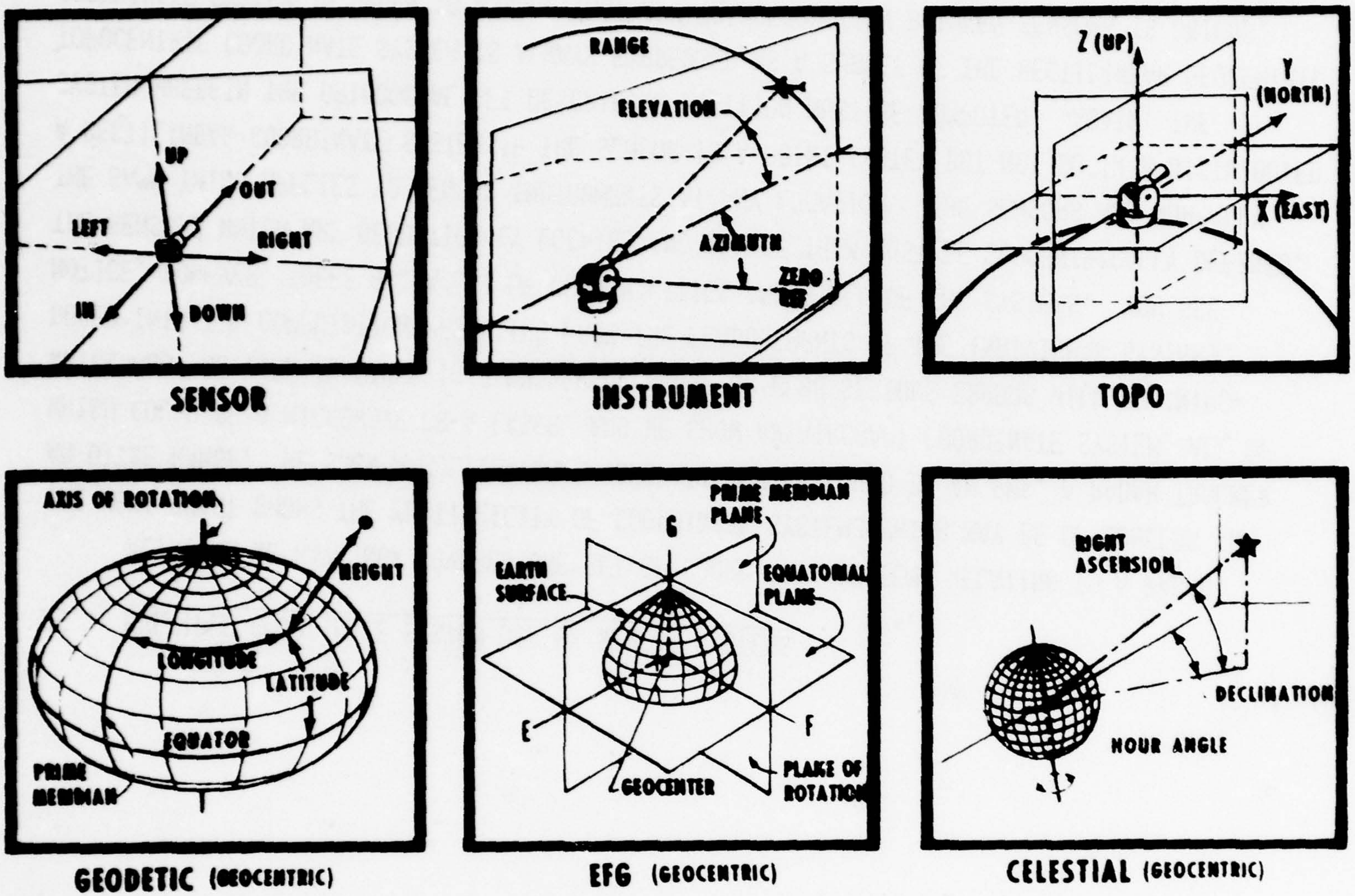
-- DERIVATIVE PROCESS

-- NOT COMPATIBLE WITH MANEUVERING TARGETS

24. COORDINATE SYSTEMS

NEXT, I WOULD LIKE TO DISCUSS COORDINATE SYSTEMS, BECAUSE THEY ARE ALSO A MATTER OF UNCERTAINTY IN THE TRAJECTORY PROCESS. IT IS THE MULTIPLICITY OF COORDINATE SYSTEMS AND THE INACCURATE TRANSFORMATIONS WHICH INFLUENCE ACCURACY. ALTHOUGH NUMERICALLY THE TRANSFORMATION BETWEEN SENSOR AND INSTRUMENT, AND BETWEEN INSTRUMENT AND TOPO ARE UNIQUE, IN PRACTICE THIS IS NEVER THE CASE SINCE THERE ARE SYSTEMATIC ERROR MODEL TERMS WHICH MUST BE ACCOUNTED FOR. TWO IMPORTANT CONSIDERATIONS WITH ALL COORDINATE SYSTEMS ARE THE LOCATION OF THE ORIGIN AND THE ORIENTATION OF THE COMPONENTS. SIX IMPORTANT RADAR COORDINATE SYSTEMS ARE SHOWN: (1) THE SENSOR WHICH IS A SINGLE POINT RATHER THAN DISTRIBUTED. THE MEASUREMENTS ARE UP/DOWN, LEFT/RIGHT AND IN/OUT, AND ARE ALWAYS AN ORTHOGONAL SET, WITH ORIGIN AT THE SENSOR. WE THEN TRANSFORM THE MEASUREMENTS TO THE (2) INSTRUMENT ON WHICH THE SENSOR IS MOUNTED, PRODUCING A NONLINEAR BUT ORTHOGONAL SET KNOWN AS RANGE, AZIMUTH AND ELEVATION. IN ORDER TO USE DATA AT OTHER LOCATIONS WE MUST TRANSFORM TO THE EARTH'S SURFACE, PRODUCING A TOPOSPHERIC (3) RECTILINEAR SET WHOSE COMPONENTS ARE EAST (X), NORTH (Y) AND UP (Z). THE ORIGIN IS EXPRESSED IN A GEODETIC (4) SYSTEM, WHICH IS ORTHOGONAL BUT NONLINEAR, AND ITS COMPONENTS ARE KNOWN AS LATITUDE, LONGITUDE AND HEIGHT. FOR STELLAR CALIBRATION PURPOSES, A CELESTIAL (5) COORDINATE SYSTEM IS USED, WHICH TWO COMPONENTS ARE RIGHT ASCENSION AND DECLINATION. SINCE BOTH (4) AND (5) ARE NONLINEAR, THESE DATA ARE IMMEDIATELY TRANSFORMED TO A RECTILINEAR GEOCENTRIC SYSTEM WHOSE COMPONENTS ARE E, F, AND G. THE TOPO SYSTEM MUST ALWAYS BE A SUBSET OF EFG.

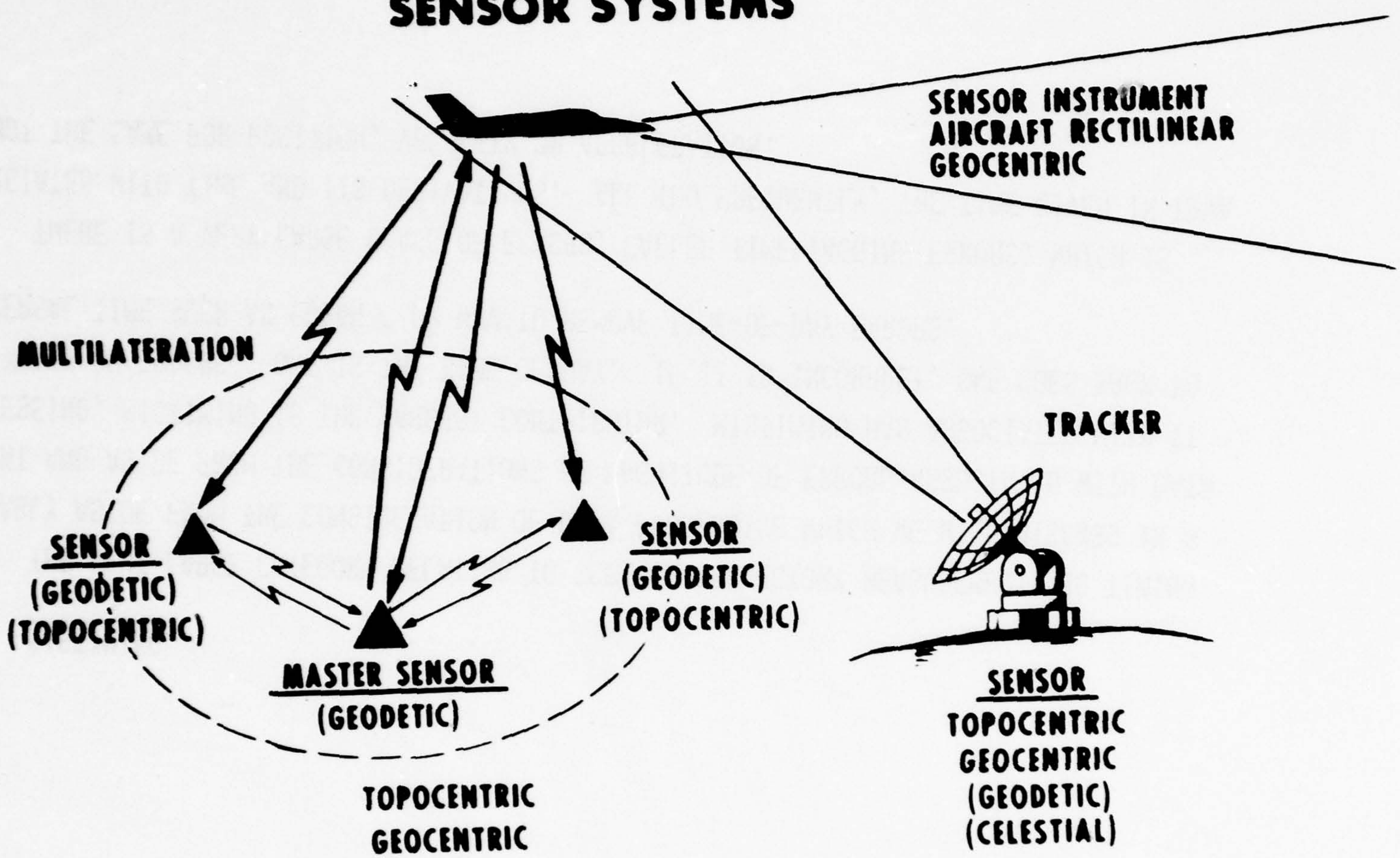
COORDINATE SYSTEMS
(ELEVATION OVER AZIMUTH MOUNT EXAMPLE)



25. <u>MULTIPLE COORDINATE SYSTEM USE BY SENSOR SYSTEMS</u>

ALTHOUGH WE HAVE NOW COVERED ONE SET OF COORDINATE SYSTEMS RELATING TO A RADAR, THE NEXT CHART SHOWS THE MULTIPLICITY OF COORDINATE SYSTEMS WHICH MAY BE OF CONCERN IN AN OTT&E RANGE. WE SHOW A MULTILATERAL SCHEMATIC WHICH COULD BE AN RMS, A RADAR TRACKER WHICH COULD BE A MICROWAVE OR A LASER, AND WE SHOW AN AIRCRAFT COORDINATE SYSTEM, ALL OF WHICH MUST BE TIED TOGETHER IN A UNIVERSAL SENSE OR ELSE SERIOUS ERRORS WILL BE INTRODUCED INTO THE COMPUTATION RESULTING FROM THE MEASUREMENTS OF THE INDIVIDUAL SYSTEMS. NOTICE, HOWEVER, THERE ARE A LOT OF COMMONALITIES AMONG ALL OF THE SYSTEMS. YOU SEE THE SENSORS WHICH ARE GEODETICALLY LOCATED AND ALL OF THEM MUST BE GEOCENTRICALLY DEFINED. THE SAME THING APPLIES TO SENSOR INSTRUMENTS AT ANY LOCATION. THE SENSORS ARE NORMALLY A RECTILINEAR COORDINATE SYSTEM IF THE SENSOR IS A POINT SYSTEM BUT NOT SO IN A DISTRIBUTED SYSTEM WHEREIN THE ORTHOGONAL SET DESCRIBING POSITION MUST BE COMPUTED. AGAIN, THE TOPOCENTRIC COORDINATE SYSTEM IS ALWAYS EXPRESSED AS A SUBSET OF THE RECTILINEAR GEOCENTRIC COORDINATE SYSTEM IN ORDER TO ASSURE THAT ANY TRANSFORMATION BETWEEN SENSORS IS UNIQUE.

MULTICOORDINATE SYSTEM USE BY SENSOR SYSTEMS

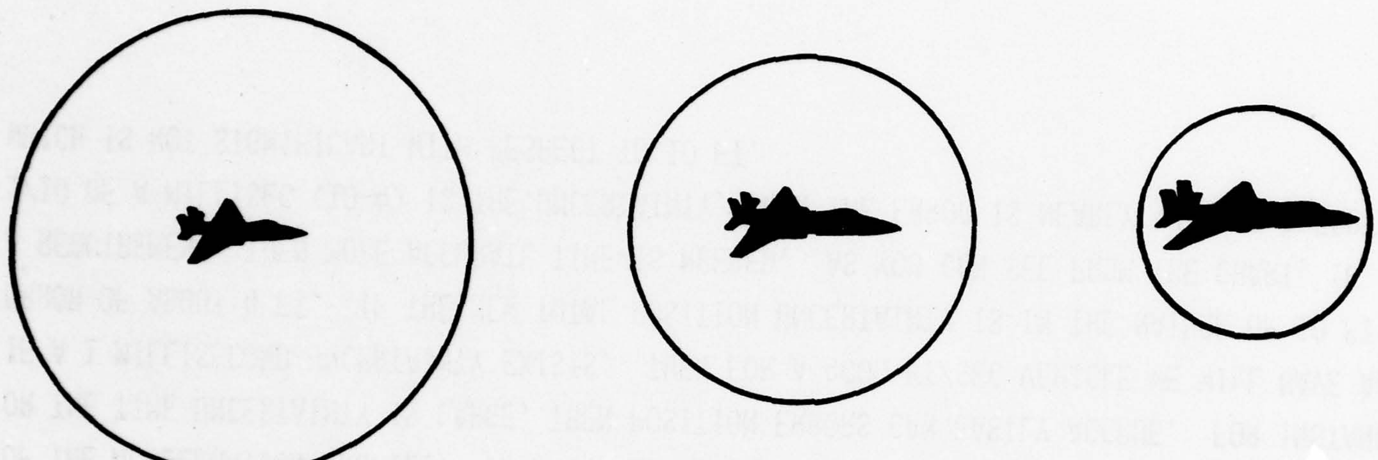


26. MISTIMING

THE NEXT LARGE CATEGORY RELATING TO TSPI OR TRAJECTORY MEASUREMENTS IS TIMING. PROBABLY ASIDE FROM THE CONSIDERATION OF DATA PROCESSING WHICH WE WILL DISCUSS IN A MOMENT AND ASIDE FROM THE CONSIDERATIONS OF MAGNITUDE OF ERRORS ASSOCIATED WITH DATA PROCESSING, MISTIMING IS THE LARGEST CONTRIBUTOR. MISTIMING HAS ASSOCIATED WITH IT TWO TYPES OF ERRORS. ONE IS THE TIME OF DAY. IF IT IS INCORRECT, ONE GOES BACK TO UNIVERSAL TIME SUCH AS LORAN C OR WWV TO REMOVE TIME-OF-DAY ERRORS.

THERE IS A VERY LARGE CLASS OF ERRORS, CALLED TIME-TAGGING ERRORS, WHICH IS ASSOCIATED WITH TIME AND ITS DERIVATIVES. ALL TOO FREQUENTLY, THE TIME GIVEN IN TPVA IS NOT THE SAME FOR POSITION, VELOCITY OR ACCELERATION.

MISTIMING
UNCERTAINTY ABOUT THE TARGET



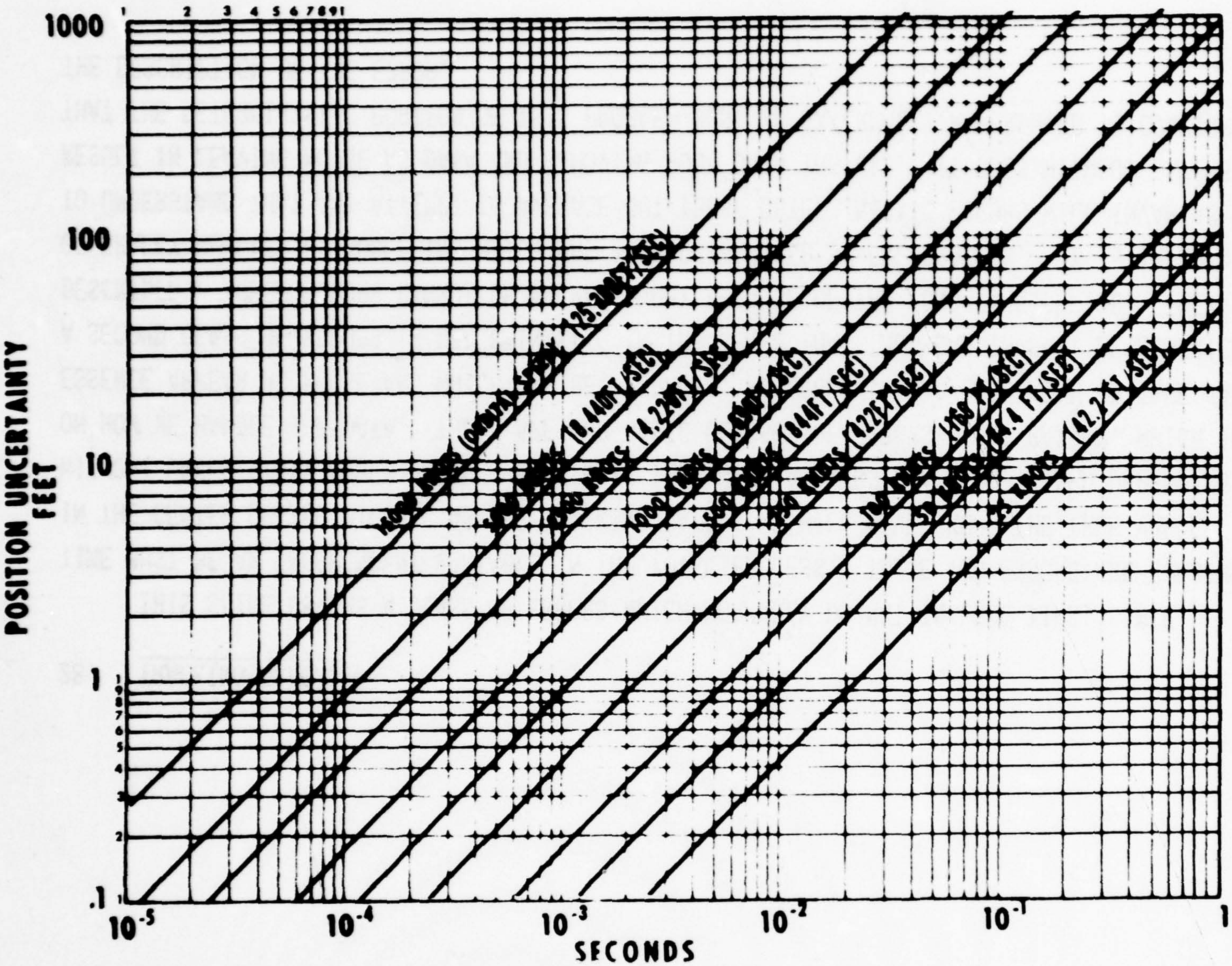
- TIME OF DAY ERRORS — UNIVERSAL time
- TIME TAGGING — ASSOCIATION OF time WITH POSITION AND DERIVATIVES

SAME —
- TIME FOR POSITION
- TIME FOR VELOCITY
- TIME FOR ACCELERATION

27. TIME UNCERTAINTY VS POSITION UNCERTAINTY

I HAVE ALREADY SHOWN YOU THE MAGNITUDE OF ERRORS ASSOCIATED WITH THE UNCERTAINTY OF THE ACCELERATION PROFILE. IN A SIMILAR MANNER, IF THE VELOCITY UNCERTAINTY IS LARGE, OR THE TIME UNCERTAINTY IS LARGE, THEN POSITION ERRORS CAN EASILY ACCRUE. FOR INSTANCE, IF A 1 MILLISECOND UNCERTAINTY EXISTS, THEN FOR A 4000 FT/SEC VEHICLE WE WILL HAVE AN ERROR OF ABOUT 4 FT. IF THE NEW TOTAL POSITION UNCERTAINTY IS IN THE NATURE OF 10 FT AS A REQUIREMENT, THEN MORE ACCURATE TIME IS NEEDED. AS YOU CAN SEE FROM THE CHART, IF 1/10 OF A MILLISEC (10-4) IS THE UNCERTAINTY, THEN THE ERROR IS NEARLY 4/10 OF A FOOT, WHICH IS NOT SIGNIFICANT WITH RESPECT TO 10 FT.

TIME UNCERTAINTY vs POSITION UNCERTAINTY

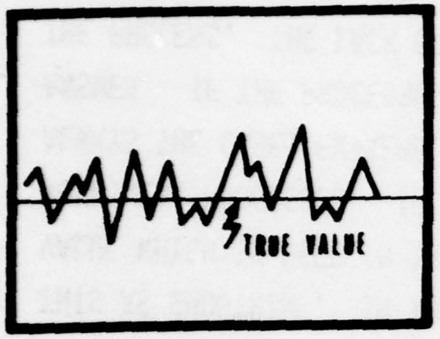


28. TRACKING ERRORS

THIS SLIDE COVERS A CLASS OF ERRORS WHICH NORMALLY DO NOT INCLUDE TIME, SINCE TIME MUST BE AN INDEPENDENT VARIABLE IN THE TOTAL PROCESS. THESE TWO ERRORS ARE COMBINED IN THE CENTER OF THE PICTURE AS THE TRACKING DATA. WE WILL NEVER KNOW THE TRUE VALUE WITHOUT UNCERTAINTY AND A PROBLEM EXISTS IN THAT MANY ANSWERS CAN BE OBTAINED DEPENDING ON HOW WE HANDLE THE DATA. THERE ARE TWO BASIC CLASSES OF ERRORS: (1) RANDOM, WHICH IN ESSENCE APPEAR AS NOISE AND WHICH CAN BE AVERAGED, HOPEFULLY, TO A ZERO MEAN OR TRUE VALUE. A SECOND CLASS OF ERRORS IS DETERMINISTIC IN THE SENSE THAT THEY CAN IN FACT BE NUMERICALLY DESCRIBED. THESE ERRORS CANNOT BE AVERAGED OUT BECAUSE OF THE LONG TIME PERIOD. THEY ARE GENERALLY REMOVED BY MODELLING WHICH HAS BEEN DETERMINED BY CALIBRATION. IT IS IMPORTANT TO UNDERSTAND THAT ANY ATTEMPT TO AVERAGE OUT THESE DETERMINISTIC ERRORS WILL INVARIABLY RESULT IN LEAVING NOISE AS DATA AND REMOVING GOOD DATA INSTEAD. IT GOES WITHOUT SAYING THAT THE DETERMINISTIC PORTION OF THIS PROBLEM MUST BE EXTERNALLY REFERENCED TO CONFIRM THE DESCRIPTION OF THE ERROR.

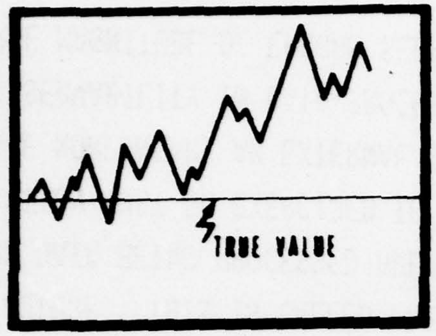
TRACKING ERRORS

RANDOM ERROR COMPONENTS



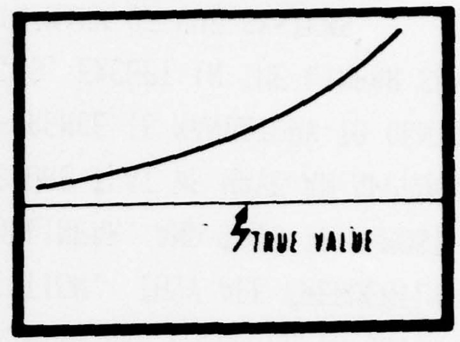
- RAPID FLUCTUATION NOISE-LIKE
- ZERO MEAN
- CAN BE AVERAGED TOWARD ZERO
- ANY ONE DATA POINT HAS ERROR

TRACKING DATA



- WILL NEVER KNOW TRUE VALUE
- MANY POSSIBLE INTERPRETATIONS WHEN PROCESSED

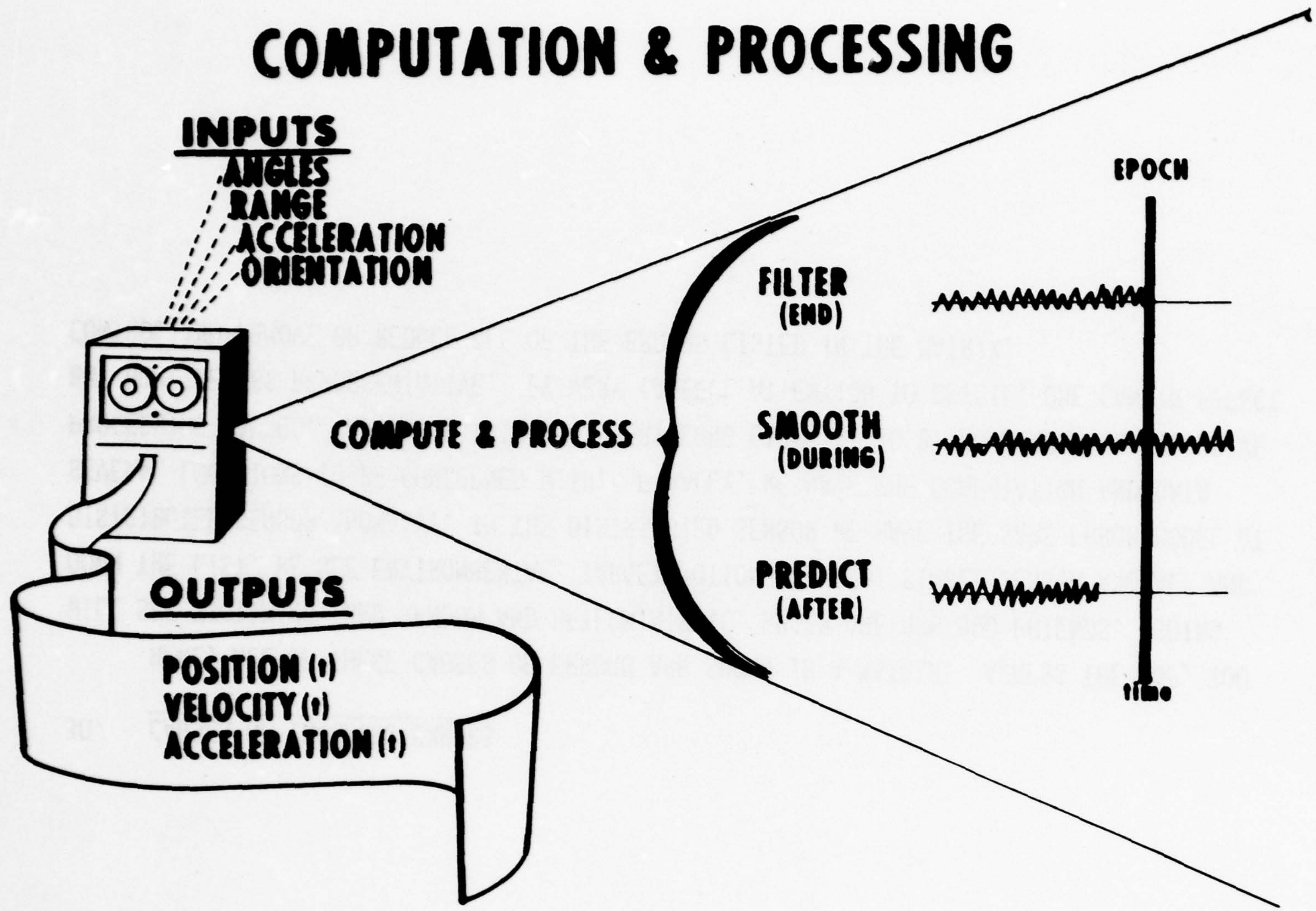
DETERMINISTIC (SYSTEMATIC) ERROR COMPONENT



- SLOWLY VARYING (CANNOT BE AVERAGED OUT)
- POSSIBLE TO OBSERVE APRIORI
- DEVELOP ERROR MODELS
- REMOVE FROM DATA
- EXTERNAL REFERENCE NEEDED TO CONFIRM

29. COMPUTATION AND PROCESSING

THIS CHART SHOWS INPUTS AND OUTPUTS. INVARIABLY, THE DATA MEASUREMENT PROCESS IS NOISY AND WE MUST DO SOME ADJUSTMENT TO CONTROL OR REMOVE THE NOISE. THIS BREAKS DOWN INTO THREE POSSIBLE TECHNIQUES. IF WE FILTER, WE ARE USING THE DATA AT THE END OF THE PROCESS. IF WE ARE USING THE DATA DURING THE PROCESS, WE GENERALLY REFER TO THIS AS SMOOTHING. IN THE THIRD CASE, SMOOTHING OR FILTERING ARE EMPLOYED TO GET A VALUE WHICH IS USED IN THE FUTURE. THIS IS CALLED PREDICTION. THEY ARE FREQUENTLY NONLINEAR PROCESSES. IF THE DATA BEING PROCESSED ARE NONLINEAR, AND THIS IS ALMOST ALWAYS THE CASE, EXTREME CAUTION MUST BE EXERCISED TO ASSURE THAT WE HAVE AN APPROPRIATE ANSWER. IF THE PROCESSES ARE NONLINEAR, AN EXTERNAL REFERENCE IS MANDATORY TO CONTROL THE PROCESS. THE LACK OF OBSERVABILITY IN DATA PROCESSING, EXCEPT IN THE LINEAR SENSE, MAY BE A REASON FOR THE LARGE MAGNITUDE OF ERRORS SEEN IN MANY OF OUR SYSTEMS.


COMPUTATION & PROCESSING
INPUTS
ANGLES
RANGE
ACCELERATION
ORIENTATION
COMPUTE & PROCESS
FILTER
(END)
SMOOTH
(DURING)
PREDICT
(AFTER)
EPOCH
time
OUTPUTS
POSITION (t)
VELOCITY (t)
ACCELERATION (t)

30. <u>CAUSES OF TRACKING ERRORS</u>

HERE, ALL OF THESE CAUSES OF ERRORS ARE SHOWN IN A MATRIX. ACROSS THE TOP, YOU WILL SEE MISTIMING, AND RANDOM AND DETERMINISTIC, WHICH ARE NOW OLD FRIENDS. GOING DOWN THE LIST, WE SEE ENVIRONMENTAL, TARGET MOTION INDUCED, SINGLE SENSOR ANOMALY AND DISTRIBUTED SENSOR ANOMALY. IN THE DISTRIBUTED SENSOR WE HAVE THE SAME ERROR MODEL AT SEVERAL LOCATIONS TO BE CONCERNED WITH. FINALLY, WE HAVE THE COMPUTATION AND DATA PROCESSING CAUSES. ALTHOUGH THIS IS A VERY LONG LIST, IT IS BY NO MEANS ALL INCLUSIVE BUT NONETHELESS REPRESENTATIVE. BY VERY CAREFUL ATTENTION TO DETAIL, ONE CAN IN EFFECT CONTROL AND REMOVE OR REDUCE ALL OF THE ERRORS LISTED IN THE MATRIX.

CAUSES OF TRACKING ERRORS

ERRORS → / ↓ CAUSES	TYPES		
	MISTIMING	RANDOM (NOISE-LIKE STATISTICAL)	DETERMINISTIC (SYSTEMATIC)
ENVIRONMENTAL	• PROPAGATION	• EFFECTS OF MULTIPATH • ATMOSPHERIC TURBULANCE • WIND GUSTS	• REFRACTION • STEADY WIND
TARGET MOTION INDUCED		• GLINT • SCINTILLATION	• TRANSIT TIME • APPARENT ACCELERATION (DYNAMIC LAG)
SINGLE SENSOR ANOMALY	• SINGLE LOCATION TIME TAGGING	• RECEIVER NOISE	• ENCODER ZERO-SET • MISS-LEVEL • SKEW • NON-ORTHOGONALITY OF AXIS • DROOP
DISTRIBUTED (MUTIPLE) SENSORS ANOMALIES	• DISTRIBUTED TIME TAGGING • DISTRIBUTED TIMING	• MUTIPLE RECEIVER NOISE	• GDOP (NON-ORTHOGONALITY OF MEASUREMENTS) • ANY OF SINGLE SENSOR • SURVEY ERRORS
COMPUTATION & DATA PROCESSING	• AVERAGE VALUES FOR DERIVATIVES	• INADEQUATE NOISE STATISTICS • UNDEFINED STARTING CONDITIONS	• INCORRECT ERROR MODELS

31. CALIBRATION

CALIBRATION IS THE PROCESS OF DISCOVERING, SORTING AND REMOVING SYSTEMATIC ERROR. THERE ARE TWO OPPOSITE METHODS OF DOING CALIBRATION, I.E., "IN-LOOP" (SERVO) AND "OUT-LOOP." IN GENERAL, THEY BOTH START WITH A SURVEY, AND AFTER THAT THERE IS LITTLE IN COMMON. IN "OUT-LOOP" THE MOUNT IS LEVELED AND NORTH, ZERO ELEVATION, AND ZERO RANGE ARE EVALUATED AT A SINGLE POINT USING A SURVEYED BORESIGHT TOWER. ALL OTHER CORRECTIONS ARE DETERMINED BY POST-FLIGHT DATA PROCESSING AND WITHOUT OBSERVABILITY AS TO THE APPROPRIATE ANSWERS. IN THE "IN-LOOP" CASE, EXACTLY THE OPPOSITE IS TRUE. ADDITIVES ARE ADDED INTO THE SERVO LOOP TO PREVENT ERRORS FROM OCCURRING AND THEIR EFFECT IS EVALUATED BY OBSERVING THE STARS AND DYNAMIC TARGETS AND THE SYSTEMATIC MODEL ADJUSTED UNTIL THE ERRORS ARE MINIMAL. FINAL ACCURACY WHICH RESULTS FROM AN EFFECTIVE CALIBRATION IS DEMONSTRATED BY ONE "IN-LOOP" SYSTEM POINTING ANOTHER AND THE DIFFERENCE DEFINES ACCURACY.

CALIBRATION

IN LOOP
(CLOSED LOOP CORRECTION)

- SURVEY
  - LATITUDE, LONGITUDE, HEIGHT
- STARS (TOTAL STATIC MODEL) (HEMISPHERIC)
  - UP, NORTH, EAST, AZIMUTH, ELEVATION, NON-ORTHO, DROOP, SKEW, ENCODER LINEARITY
- RANGE ZERO
  - DELAY LINE, SATELLITE
- MICROWAVE/OPTICS ALIGNMENT
  - DYNAMIC TARGETS NON-ORTHO, DROOP, SKEW, REFRACTION
- DYNAMIC MOUNT MAPPING (K_a DETERMINATION)
- USE VERY DYNAMIC TARGET TO EVALUATE DYNAMIC LIMITS OF SYSTEM (NO LAG)
- DURING MISSION OBSERVE THE TARGET IN BORESIGHT OPTICS TO VERIFY CALIBRATION COUPLED WITH STELLAR OBSERVATION
- VERIFICATION OF CALIBRATION BY DRIVING SEPARATE AUTONOMOUS IN-LOOP SYSTEM TO FOLLOW DYNAMIC TARGET
  - ALSO ALLOWS CALIBRATION OF SMALL TIMING AND GEODETIC DIFFERENCES IN SYSTEMS

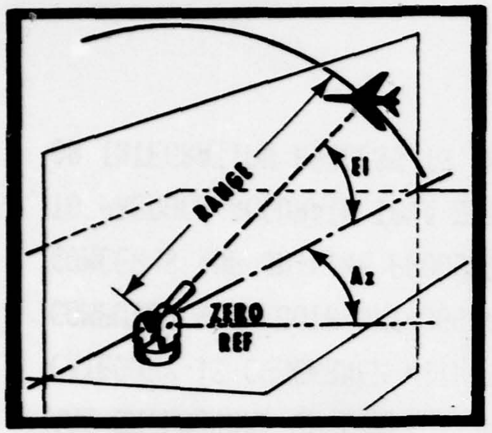
OUT LOOP
(OPEN LOOP CORRECTION)

- SURVEY
  - LATITUDE, LONGITUDE, HEIGHT
- ON SITE MEASUREMENT (SINGLE POINT)
  - LEVEL (UP)
  - BORESIGHT TARGET (NORTH, ZERO ELEVATION) ZERO RANGE
- ALL THE REST IS THEORETICAL
- SYSTEMATIC ERROR COMPUTED FROM PAST DATA
- CAN'T AGREE ON MODEL
- ALL ERRORS ARE EVALUATED TOGETHER WITH ILL-DEFINED CORRELATION
- DATA ARE THEN CORRECTED OPEN LOOP (NON-OBSERVABLE)

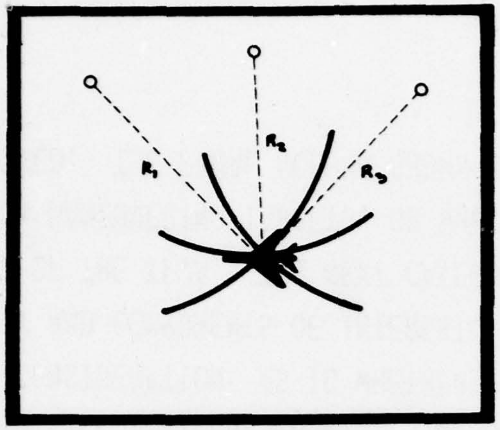
32. POSITION MEASURING INSTRUMENT SYSTEMS

TPVA SYSTEMS IN GENERAL CAN ONLY MEASURE POSITION OR COMPONENTS OF POSITION. EVEN IN THE INITIAL PLATFORM, THE SYSTEM MUST BE INITIALIZED WITH A POSITION. THE POSITION IN LEAST DATA SENSE MUST BE AN ORTHOGONAL SET OF DATA RELATING THE LOCATION TO A WELL DEFINED COORDINATE SYSTEM. SENSORS MAY BE CATEGORIZED AS SINGLE OR DISTRIBUTED SENSORS. A SINGLE SENSOR MAKES ITS MEASUREMENTS AT ONE LOCATION, WHILE THE DISTRIBUTED SENSOR WILL MAKE PARTIAL POSITION MEASUREMENTS AT SEVERAL LOCATIONS. THESE PARTIAL MEASUREMENTS MUST BE COMBINED INTO A SINGLE, THREE-COMPONENT ORTHOGONAL (INDEPENDENT) SET. IN THE SINGLE SENSOR CATEGORY ARE THE RADAR, A RANGE MEASURING SYSTEM USING A DISTRIBUTED SOURCE SUCH AS GPS, AND ALSO INCLUDED IN THE SINGLE LOCATION SENSOR IS THE INERTIAL PLATFORM CALLED A TRANSPOSITIONAL SENSOR. AMONG THE DISTRIBUTED SENSORS ARE THE ANGLE (NONLINEAR) SYSTEMS SUCH AS THEODOLITES AND DISTRIBUTED RANGING SYSTEMS SUCH AS THE RMS-II. THESE SYSTEMS COMPUTE OR MEASURE POSITION, HOPEFULLY, THE CORRECT POSITION AND THEY EVALUATE THE DERIVATIVES BY COMPUTATION.

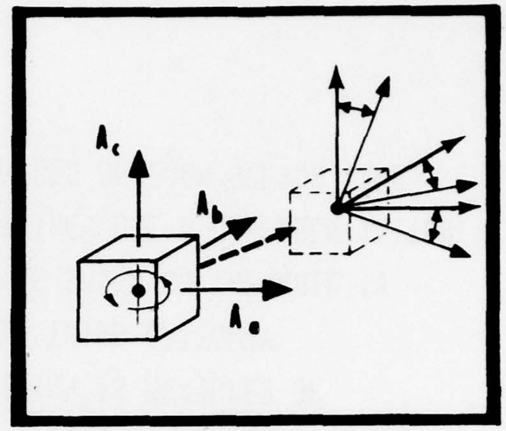
POSITION MEASURING INSTRUMENT SYSTEMS



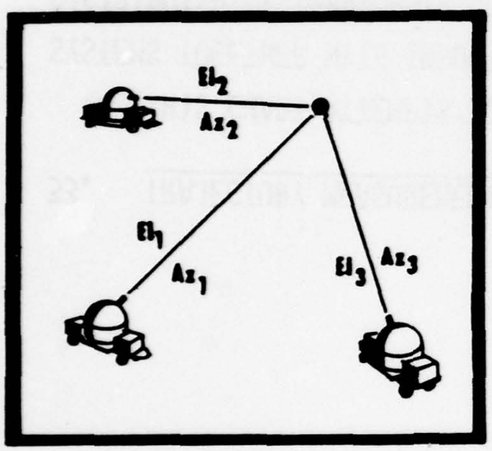
SINGLE SENSOR
(ANGLE &RANGE) (ORTHOGONAL)



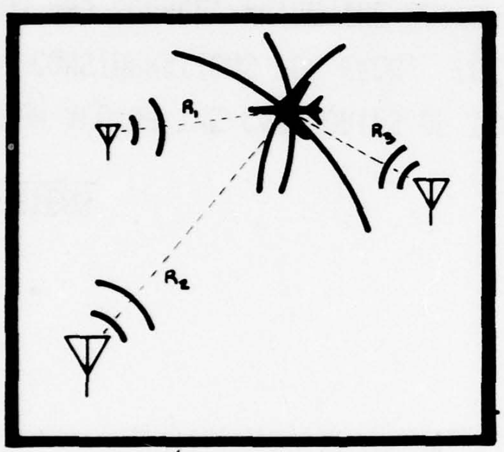
SINGLE SENSOR
(RANGE) (NON-ORTHOGONAL)



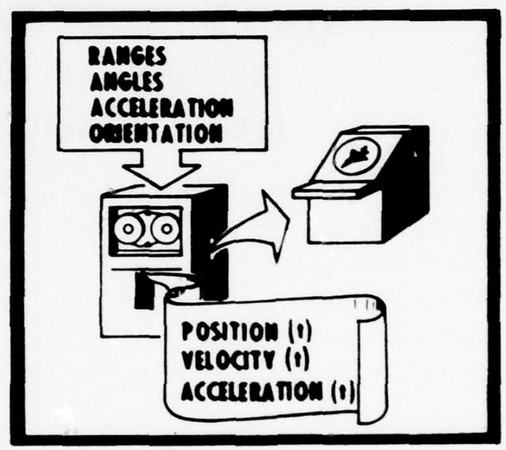
TRANSPOSITION SENSORS
(ACCEL & ORIENTATION) (ORTHOGONAL)



DISTRIBUTED SENSORS
(ANGLES) (NON-ORTHOGONAL)



DISTRIBUTED SENSORS
(RANGE) (NON-ORTHOGONAL)



TPVA

33. TRAJECTORY MEASUREMENT SYSTEMS

THIS CHART ATTEMPTS TO SHOW ALL OF THE CATEGORIES OF TRAJECTORY MEASUREMENT SYSTEMS TOGETHER WITH IMPORTANT CONSIDERATIONS FOR EACH. THE TOP HALF GIVES THE DISTRIBUTED SYSTEMS, BOTH SENSOR AND SOURCE, WHILE THE BOTTOM HALF COVERS THE SINGLE POINT SENSORS. ACROSS THE TOP ARE THE CATEGORIES OF MEASURED COMPONENTS, WHETHER THEY ARE ORTHOGONAL OR LINEAR, AND WHETHER THEY ARE MADE AT A SINGLE EPOCH. A SECOND CATEGORY IS CONCERNED WITH THE CONSIDERATION AS TO WHETHER POSITION IS MEASURED OR COMPUTED WITH BOTH ORTHOGONALITY AND COMPONENTS OF INTEREST. THE THIRD CATEGORY CONCERNS THE ON-LINE PRODUCTION OF THE TPVA. THE NEXT CATEGORY IS BASED ON THE ABILITY TO PRODUCE ACCURATE TPVA DATA ON MANEUVERING TARGETS, OR WHETHER THEY USE A DIFFERENTIATION, OR INTEGRATION PROCESS IS INVOLVED. THE FINAL COLUMN SHOWS EXAMPLES OF EACH SENSOR TYPE.

TRAJECTORY MEASUREMENT SYSTEMS

	SENSOR	MEASUREMENT COMPONENTS			MEASURED POSITION (NOT COMPUTED)		STATE VECTOR ON LINE	ACCURATE TRAJECTORY MANEUVERING TARGETS	EXAMPLES
		ORTHOG	LINEAR	SINGLE EPOCH	ORTHOG	COMPONENTS			
DISTRIBUTED	ELECTRONIC ANGLE	NO	NO	NO	NO	NO	NO	NO	MATTS
	MECHANICAL ANGLE	YES	NO	NO	NO	NO	NO	NO	THEODOLITE
	ELECTRONIC RANGE	NO	YES	NO	NO	NO	YES	NO	RMS-II ACMI
	SOURCE RANGE	NO	YES	YES	NO	NO	YES	NO	GPS
	SOURCE ANGLE	NO	NO	YES	NO	NO	NO	NO	VOR
SINGLE POINT	CONVENTIONAL RADAR	YES	NO	YES	YES	YES	NO	NO	FPS-16 PATS
	IN-LOOP INTEGRATION CONTROL (ILIC)	YES	YES	YES	YES	YES	YES	YES	FPQ-13
	TRANSLATION GYRO/ACCEL	YES	YES	YES	YES	NO	NO	YES	ARIS

34. IN-LOOP INTEGRATION CONTROL (ILIC)

ONE OF THE IMPORTANT CONSIDERATIONS IN THE DESIGN OF ILIC IS THE SEPARATION AND INDEPENDENCE BETWEEN THE RANDOM AND SYSTEMATIC PROCESSES. IT IS POSSIBLE THAT ONE OF THE PROCESSES COULD BE CORRECT WHILE THE OTHER IS NOT. IF THE RANDOM PROCESS (INTEGRATION CONTROL) IS CORRECT, THEN THE TARGET MUST REMAIN IN THE CENTER OF THE FIELD OF VIEW OF THE SENSOR. THE SYSTEMATIC ERROR MODEL IS PHYSICALLY RATHER THAN THEORETICALLY DETERMINED, AND EACH OF THE TERMS IS INDEPENDENT AND RECURSIVELY EVALUATED. SINCE WHEN USING INTEGRATION CONTROL, THE INTEGRATION NUMERICS ASSURE THAT ALL DERIVATIVES ARE TIME-TAGGED CORRECTLY, BY FAR THE MOST IMPORTANT ASPECT OF ILIC IS THAT THE EFFECTS OF DATA PROCESSING ARE DIRECTLY OBSERVABLE AND VISUALLY RECORDED.

IN-LOOP INTEGRATION CONTROL

-- RANDOM PROCESS INDEPENDENT OF SYSTEMATIC ERROR MODEL

-- SYSTEMATIC ERRORS PHYSICALLY MODELLED - INDEPENDENT AND RECURSIVE

-- INTEGRATION CONTROL PREVENTS TIME TAGGING ERRORS

-- DATA PROCESSING EFFECTS OBSERVABLE

35. IN-LOOP INTEGRATION CONTROL (CONT'D)

I REALLY WANT TO STRESS A POINT HERE. THE SYSTEMATIC ERRORS ARE MODELLED BY DIRECT OBSERVATION. RATHER THAN TRY TO MODEL THE SYSTEM FOR EACH ERROR, THE ILIC PROCESS TRIES TO MODEL A "PERFECT SYSTEM," AND TO MAKE OUR PHYSICAL MODEL BEHAVE IN THE DESIRED MANNER. AN EASILY UNDERSTOOD EXAMPLE IS THE NONORTHOGONALITY FUNCTION IN AN AZIMUTH OVER ELEVATION MOUNT. IF THE MOUNT WERE PERFECT, AS ELEVATION IS INCREASED, ONE SHOULD NOT DISCERN A CHANGE IN AZIMUTH. BY LOOKING AT A SERIES OF STARS WHICH ARE ON A SINGLE AZIMUTH, ONE CAN NOTE THE AZIMUTH CHANGE NEEDED TO SEE THE STAR AS ELEVATION IS INCREASED. BY ADDING THESE DATA TO THE DRIVE COMMAND, ONE CAN NOW INCREASE ELEVATION WITHOUT SEEING ANY CHANGE IN AZIMUTH. PLEASE NOTE THAT THIS IS A PHYSICAL CORRECTION AND NOT A DETAILED MATHEMATICAL ONE. ALTHOUGH IT MAY BE POSSIBLE FOR THE MATHEMATICAL AND PHYSICAL MODELS TO AGREE, THEY NEVER DO IN PRACTICE. IT GOES WITHOUT SAYING, "NEVER MIX THE PHYSICAL CORRECTION WITH ONE MATHEMATICALLY DERIVED FROM POST-FLIGHT ANALYSIS.

IN-LOOP INTEGRATION CONTROL (CONT'D)

1. SYSTEMATIC ERRORS MODELLED BY DIRECT OBSERVATION
2. "PERFECT SYSTEM"
3. EXAMPLE NON-ORTHO
4. PHYSICAL MODEL ACCOMMODATED
5. MATH MODEL NOT AGREE
6. DO NOT MIX PHYSICAL CORRECTION WITH MATHEMATICALLY DERIVED

36. PROOF OF CALIBRATION (VIDEO TAPE)

WITHIN EACH ILIC IS A VIDEO RECORDER/PLAYBACK CAPABILITY. A SERIES OF VIDEO RECORDINGS IS AVAILABLE FOR "PROOF OF CALIBRATION" ON EACH MISSION. THESE INCLUDE SIX INDEPENDENT EVALUATIONS RECORDED IN SUCCESSION ON A SINGLE VIDEO TAPE. ONE (1) IS A ZERO DYNAMIC LAG DEMONSTRATION TO ASSURE THAT THE MOUNT CAN FOLLOW TARGET DYNAMICS WITHOUT ERROR. THE (2) SECOND IS THE ABILITY TO POINT TO AT LEAST 20 STARS RANDOMLY DISTRIBUTED THROUGHOUT THE HEMISPHERE OF OBSERVATION TO THE PRECISION OF THE SYSTEM AS A DEMONSTRATION OF STATIC CALIBRATION. THIRD (3) IS A DEMONSTRATION THAT THE MICRO-WAVE SENSOR IS ALIGNED WITH THE OPTICALLY CALIBRATED MOUNT. THIS MAY BE VERIFIED BY A VIDEO RECORDING OF THE DIFFERENCE BETWEEN A COMPUTED TARGET POSITION AND ITS OBSERVED LOCATION ON THE VIDEO SCREEN. THEY MUST COINCIDE TO THE PRECISION OF THE SYSTEM. THE TARGET IS GENERALLY A SATELLITE; HOWEVER, ANY TARGET, SUCH AS A SPHERE, BALLOON OR AIRCRAFT, MAY BE USED PROVIDED IT MOVES FROM ONE EXTREME IN ELEVATION TO THE OTHER. FOURTH (4), A MANEUVERING TARGET (AIRCRAFT) MUST BE FLOWN TO DEMONSTRATE THE ACCELERATION LIMITS WHICH THE SYSTEM IS CONFIGURED FOR. (5) AS A VALIDATION OF THE DATA OUTPUT, ONE ILIC SYSTEM TRACKS A TARGET, AND ITS OUTPUT DATA ARE USED TO DRIVE (POINT) A REMOTE ILIC SYSTEM. DEVIATIONS FROM THE CROSS HAIRS IN THE DRIVEN SYSTEM ESTABLISH THE ACCURACY OF BOTH SYSTEMS. AND (6) FINALLY, IF THE SYSTEM (ILIC) DATA ARE USED DURING THE MISSION TO DRIVE A REMOTE TELESCOPE WHOSE RESOLUTION IS MUCH GREATER THAN THE SYSTEM UNDER TEST, ACCURACY IS WELL DEFINED.

PROOF OF CALIBRATION
(VIDEO TAPE)

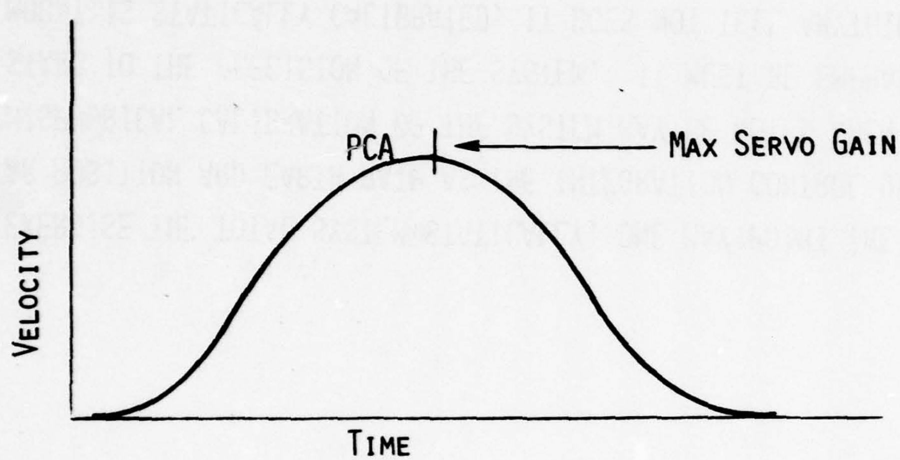
1. DYNAMIC LAG
2. 20 STARS
3. TRACK POINT CALIBRATION (SAT)
4. MANEUVERING TARGET
5. ONE RADAR DRIVES ANOTHER
6. VALIDATION - LONG FOCAL LENGTH

37. DYNAMIC LAG

WITHIN THE INTEGRATION CONTROL LOOP, ONE MUST ASSURE THAT THE TOTAL SYSTEM CAN HANDLE THE DYNAMIC TARGET OF CONCERN. THIS IS DONE BY MAPPING THE MOUNT INTO THE CONTROL DEVICE. ANY SERVO WILL LAG DEPENDENDING ON THE TYPE (ORDER) OF THE SERVO AND THE DERIVATIVES IN THE DRIVING DATA. IN THE ILIC PROCESS A VERY DYNAMIC SYNTHETIC TARGET TRAJECTORY IS USED TO DRIVE THE MOUNT. THE MOUNT WILL LAG AND THIS LAG IS RECORDED BY THE CONTROLLER AND IS ADDED ON THE DEMONSTRATION RUN. A DISPLAY OF THE DESIGNATED DIFFERENCES ON THE VIDEO TAPE GIVES AN INDICATION THAT THE MOUNT IS FOLLOWING THE SYNTHETIC TRAJECTORY WITH ZERO LAG. IF THIS TEST IS NOT VALIDATED, THEN THE SYSTEM MIGHT LAG ON A MISSION.

DYNAMIC LAG

- SYNTHETIC TARGET
- MAXIMUM ACCELERATION EXPECTED
- ZERO LAG (DESIGNATE DIFFERENCE)



38. <u>20 STARS</u>

IN ORDER TO EXERCISE THE TOTAL SYSTEM STATICALLY, ONE MAY POINT THE INSTRUMENT AT STARS USING THE STAR POSITION AND EARTH RATE AS THE INTEGRATION CONTROL DRIVE. A DEMONSTRATION OF THE HEMISPHERICAL CALIBRATION OF THE SYSTEM MAY BE NOTED WHEN POINTING AT 20 OR MORE RANDOM STARS TO THE PRECISION OF THE SYSTEM. IT MUST BE EMPHASIZED THAT THIS VERIFIES THAT THE MOUNT IS STATICALLY CALIBRATED; IT DOES NOT TELL ANYTHING ABOUT THE MICROWAVE OR OTHER SENSOR BEING USED.

20 STARS

-- RANDOMLY DISTRIBUTED

-- HEMISPHERE

-- TESTS TOTAL SYSTEM

-- STATIC

-- OPTICAL/MOUNT

39. <u>TRACK POINT</u>

A MAPPING OF THE MICROWAVE TRACKING CAPABILITY MUST BE MADE ONTO THE ALREADY CALIBRATED MOUNT/OPTICAL SYSTEM. THIS IS DONE BY PREDICTING WHERE THE TARGET SHOULD APPEAR IN THE BORESIGHT OPTICS, WHILE THE MICROWAVE SENSOR IS POINTED DIRECTLY AT THE TARGET. THE COMPUTED EXPECTED LOCATION OF THE TARGET IS KNOWN AS THE TRACK POINT, AND THIS CHANGES WITH ELEVATION. WHEN THE DIFFERENCE BETWEEN THE CALCULATED TRACK POINT AND THE IMAGE OF THE TARGET IS WITHIN THE PRECISION OF THE SYSTEM, THEN THE TRACK POINT IS WELL DEFINED. THIS DEMONSTRATION ASSURES THAT THE MICROWAVE/OPTICAL SYSTEMS ARE CALIBRATED.

TRACK POINT

-- HIGH ELEVATION

-- SATELLITE PREFERRED

-- COMPUTED TARGET POSITION

-- ACTUAL TARGET POSITION

-- ZERO DIFFERENCE

-- MICROWAVE/OPTICAL

40. MANEUVERING TARGET

ALTHOUGH IN THE DYNAMIC LAG DEMONSTRATION WE HAVE ASSURED THAT THE MOUNT WILL FOLLOW THE REQUIRED COMMAND, WE MUST NOW ASSURE THAT THE CORRECT COMMAND IS CAPABLE OF BEING GENERATED. THIS TEST DEMONSTRATION MUST ONLY BE DONE ONCE, UNLESS THE SYSTEM CONFIGURATION HAS CHANGED. IF DOUBT EXISTS, DO THIS TEST, RATHER THAN FIND OUT ON A LIVE MISSION. GENERALLY AN AIRCRAFT IS USED BECAUSE IT MAY PERFORM THE NECESSARY MANEUVERS. MAKE SURE THAT THE AIRCRAFT EXCEEDS THE MANEUVERS WHICH WILL BE PERFORMED ON THE SYSTEM UNDER TEST. THE NECESSARY DEMONSTRATION MUST SHOW THAT THE TARGET AND TRACK POINT STAY AT ZERO DIFFERENCE UNDER MANEUVERING CONDITIONS. MAKE SURE THAT THE TARGET IS OBSERVED AT HIGH AS WELL AS LOW ELEVATION ANGLES. WHEN THE DIFFERENCE BETWEEN THE TRACK POINT AND THE PREDICTED POSITION, I.E., ΔUP/DOWN AND ΔLEFT/RIGHT, STAY WITHIN THE PRECISION OF THE SYSTEM, THEN THE SYSTEM IS DYNAMICALLY CALIBRATED.

MANEUVERING TARGET

-- AIRCRAFT

-- TURNS, CLIMB, DIVE

-- MUST MATCH TEST MANEUVERING

-- BORESIGHT STAY ON TARGET

-- HIGH/LOW ELEVATION

-- RECORD ΔUP/DOWN AND ΔLEFT/RIGHT

-- TO PRECISION OF SYSTEM

41. DATA DEMONSTRATION

ILIC SYSTEMS SHOULD BE OPERATED IN PAIRS PRIMARILY SO THAT A VALID ACCURACY DEMONSTRATION MAY BE AVAILABLE. THIS IS BASED ON THE FACT THAT IF THERE ARE TWO AUTONOMOUSLY CALIBRATED SYSTEMS AND ONE DRIVES (POINTS) THE OTHER AND THE DYNAMICS ARE GREAT ENOUGH, THEN THE ERROR SEEN IN THE DRIVEN SYSTEM BORESIGHT IS A MEASURE OF ACCURACY. ONCE THE ERROR IS CONTAINED WITHIN THE PRECISION OF EITHER SYSTEM, ACCURACY IS WELL DEFINED AND ON-LINE. IT PAYS TO CHANGE THE DRIVER AND THE DRIVEN TO DEMONSTRATE THAT THE SAME ANSWERS ARE AVAILABLE AS BEFORE AND THAT EACH SYSTEM PRODUCES IDENTICAL DATA.

MONSTRATION

ALIBRATED SENSORS

ERATION

BORESIGHT OF DRIVEN SYSTEM

DATA EVALUATED

DRIVEN

EACH SYSTEM PRODUCES IDENTICAL DATA

DATA DEMONSTRATION

-- TWO AUTONOMOUSLY CALIBRATED SENSORS

-- ONE DRIVES OTHER

-- USE CHANGING ACCELERATION

-- ERROR EVALUATED IN BORESIGHT OF DRIVEN SYSTEM

-- DIFFERENCE IN TPVA DATA EVALUATED

-- CHANGE DRIVER AND DRIVEN

-- DEMONSTRATES THAT EACH SYSTEM PRODUCES IDENTICAL DATA

42. VALIDATION

ONE COULD CONCLUDE THAT THE LAST FIVE DEMONSTRATIONS ARE ADEQUATE, AND SUCH IS THE CASE. IN THE INTEREST OF MISSION CONTROL AND DATA VERIFICATION, ONE CAN OBSERVE THE TARGET WITH A LONG FOCAL LENGTH TELESCOPE. IF THE FOCAL LENGTH IS LONG ENOUGH, THEN THE RESOLUTION BY THE TELESCOPE MUST BE GREATER THAN THE OTHER DATA COLLECTION SENSORS. WHERE THE REMOTE TELESCOPE IS AUTONOMOUSLY (ILIC) CALIBRATED, THE ACCURACY OF THE MISSION DATA IS OBSERVED ON-LINE. ANY DEVIATION OF THE TARGET FROM THE RETICLE IS ERROR IN THE DATA COLLECTED.

VALIDATION

-- USE TPVA DATA FROM SENSOR TO DRIVE REMOTE AUTONOMOUSLY CALIBRATED LONG FOCAL LENGTH TELESCOPE

-- INSURE THAT TELESCOPE GIVES PROOF OF CALIBRATION AS ABOVE

-- DEVIATION OF TARGET FROM RETICLE IS ERROR

43. <u>DATA CONFIRMATION</u>

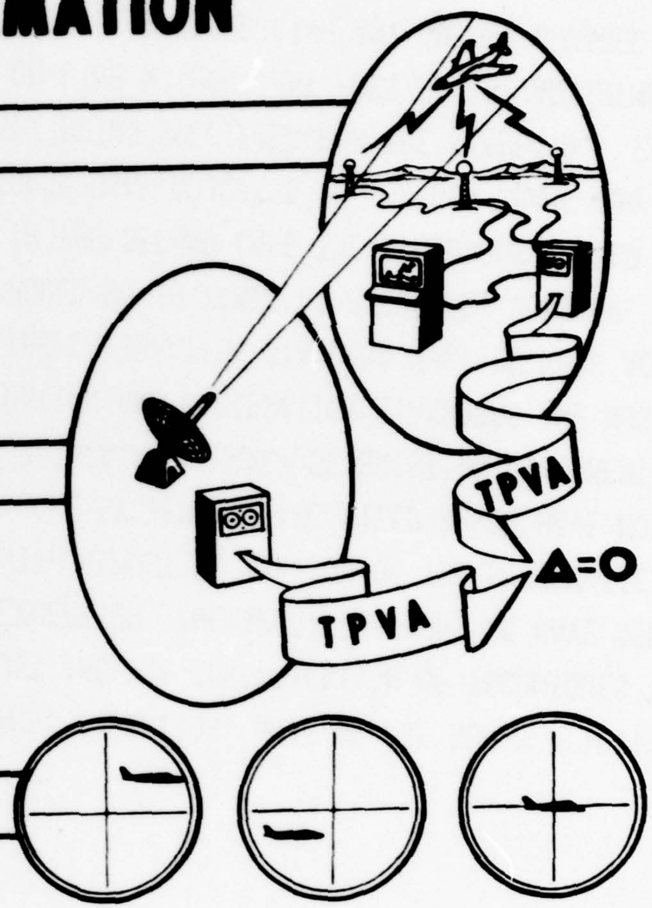
THIS SLIDE INTENDS TO SHOW THAT A DATA PROCESSING SYSTEM REALLY CANNOT CHECK ITSELF AND MUST HAVE SOME STANDARD AGAINST WHICH IT CAN IN FACT OBSERVE ITS ERRORS AND ADJUST ITSELF (CALIBRATE) UNLESS THE DIFFERENCE BETWEEN THE TWO IS ZERO. WHEN ONE CAN INSURE THAT THIS CONDITION EXISTS, BOTH SYSTEMS ARE CALIBRATED; HOWEVER, THE NEXT SLIDE INTENDS TO SHOW IN SUMMARY WHAT WE CONSIDER TO BE ABSOLUTELY NECESSARY STEPS TO TAKE.

DATA CONFIRMATION

DOUBT SINGLE SYSTEM

USE ANOTHER SYSTEM

OBSERVABILITY



44. SUMMARY

IT GOES WITHOUT SAYING THAT, ALMOST WITHOUT EXCEPTION, WHAT WE ARE NOW MENTIONING IS NOT BEING DONE. THE PROCUREMENT PROCESS MUST INCLUDE SPECIFICATION OF TECHNIQUES TO VERIFY AND MAINTAIN ACCURACY. AGAIN ALMOST WITHOUT EXCEPTION, THE SPECIFICATIONS WE HAVE SEEN HAVE ONLY TALKED ABOUT SMOOTHNESS OR RANDOM ERROR WITH ALMOST NO MENTION OF THE SYSTEMATIC PROCESS. THE SECOND POINT HERE IS THAT WE ALREADY HAVE SOME SYSTEMS IN THE FIELD WHICH HAVE NOT BEEN CHECKED, AND WE MUST TAKE STEPS TO VERIFY AND MAINTAIN ACCURACY OF EXISTING EQUIPMENT. SINCE THE REAL PROBLEM IS THE LACK OF ADEQUATE EVALUATION AND CALIBRATION STANDARDS, WE MUST DEVELOP EQUIPMENT WHICH WILL SATISFY THE FOLLOWING: THE CALIBRATION STANDARD MUST BE MORE ACCURATE THAN THE SYSTEM BEING CHECKED. NORMALLY IT SHOULD BE 10 TIMES AS ACCURATE; HOWEVER, THE DEMONSTRATION OF SUPERIOR ACCURACY IS MANDATORY. IN THE SECOND CASE THE STANDARDS SHOULD BE OPERATED IN PAIRS SO THAT EACH ONE MAY BE AUTONOMOUSLY ADJUSTED IN ITS OWN FRAME AND THAT ONE CAN DRIVE THE OTHER TO DEMONSTRATE THE ACCURACY BEING SPECIFIED FOR THE STANDARD. THE THIRD POINT MADE IS THAT THE DATA MUST BE PRODUCED ON-LINE WITHOUT ANY POST-FLIGHT ADJUSTMENT OR CORRECTION, SINCE, IN POST-FLIGHT, ONE CAN ADJUST THE DATA TO GIVE ANY ANSWER DESIRED SIMPLY BY ELIMINATING SPECIFIC DATA. FINALLY, THE STANDARD MUST BE TRANSPORTABLE. TSPI SYSTEMS ARE DISTRIBUTED ALL OVER, GEOGRAPHICALLY, AND THE PROBABILITY THAT WE CAN TAKE THESE SYSTEMS TO THE STANDARD IS VERY LOW INDEED, AS IS EVIDENT BY THE FACT THAT IN THE PAST, VERY LITTLE, IF ANY, CALIBRATION/VERIFICATION HAS TAKEN PLACE.

SUMMARY

PROCUREMENT PROCESS MUST INCLUDE SPECIFICATION OF TECHNIQUES TO VERIFY AND MAINTAIN ACCURACY.

SIMILAR TECHNIQUES MUST BE DEVISED TO VERIFY AND MAINTAIN ACCURACY OF EXISTING EQUIPMENT.

ADEQUATE EVALUATION AND CALIBRATION STANDARDS MUST BE DEVELOPED WHICH MUST SATISFY THE FOLLOWING:

- BE MORE ACCURATE THAN SYSTEM BEING CHECKED,
- BE OPERATED IN PAIRS TO VERIFY THE ACCURACY OF THE STANDARD,
- MUST PROVIDE ON-LINE (REAL TIME) TRAJECTORY DATA, AND
- MUST BE TRANSPORTABLE, ALTHOUGH IT IS RECOGNIZED THAT, FOR SPECIAL APPLICATIONS, FIXED (DEDICATED) STANDARDS MAY BE NEEDED.

45. STANDARDS PROGRAM

THERE IS A CRITICAL NEED FOR A TRAJECTORY STANDARDS PROGRAM. ALTHOUGH THERE MAY BE OTHER TECHNIQUES WHICH CAN PERFORM THE STANDARDS, ILIC HAS DEMONSTRATED ITS POTENTIAL IN THIS AREA. IT IS, HOWEVER, DIFFERENT AND MUST BE CALIBRATED IN A RECURSIVE AND AUTONOMOUS MANNER. IT IS NOT AMENABLE TO POST-FLIGHT MANIPULATION. A MINIMAL PROGRAM SHOULD BE STARTED IN WHICH THE CALIBRATION VERIFICATION MUST BE CONTROLLED BY A SEPARATE OBJECTIVE AND KNOWLEDGEABLE GROUP. IT MUST NOT BE CONTROLLED BY HARDWARE CONTRACTORS, RANGE USERS OR RANGE OPERATORS. THE MINIMAL PROGRAM SHOULD START WITH TWO SEPARATE CONTRACTS UNDER THE CONTROL OF A KNOWLEDGEABLE GOVERNMENT AGENCY, ONE TO BUILD THE EQUIPMENT AND ONE TO CONTROL AND ASSURE VALID CALBRATION, OPERATION AND DATA PRODUCTION.

STANDARDS PROGRAM

ILIC CAN PROVIDE THE ACCURACY NEEDED AS A STANDARD FOR CALIBRATION, BUT

- -- WILL DO THIS ONLY IF PROPERLY CALIBRATED ITSELF
    - -- NOT MORE DIFFICULT THAN OTHER SYSTEMS - ONLY DIFFERENT
    - -- MUST BE CALIBRATED ON-SITE IN A RECURSIVE, AUTONOMOUS FASHION
    - -- IT IS <u>NOT</u> AMENABLE TO POST-FLIGHT MANIPULATION, SINCE ERROR TERMS ARE PHYSICALLY OBSERVED RATHER THAN THEORETICALLY MODELED
- -- AS WITH ANY STANDARD, THE CALIBRATION SHOULD BE CONTROLLED BY A SEPARATE, INDEPENDENT, OBJECTIVE AND KNOWLEDGEABLE GROUP (BOTH GOVERNMENT AND CONTRACTOR), NOT BY THE HARDWARE CONTRACTOR
- -- STANDARD SHOULD NOT BE CONTROLLED BY RANGE USERS OR OPERATORS
- -- TWO CONTRACTS UNDER THE CONTROL OF A KNOWLEDGEABLE GOVERNMENT AGENCY ARE RECOMMENDED:
    - -- ONE TO BUILD AND OPERATE THE EQUIPMENT
    - -- ONE TO CONTROL THE SYSTEM CALIBRATION, OPERATION AND DATA PRODUCTION

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THE NEED FOR TRACKING SYSTEM CAPABILITY VERIFICATION/CALIBRATIO--ETC(U)
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46. CONCLUSION

THERE IS AT LEAST ONE VERY SIGNIFICANT VOID IN CURRENT RANGE CAPABILITIES, I.E., AN ON-LINE TRANSPORTABLE TRAJECTORY STANDARD. THERE IS ALSO A SIGNIFICANT UNCERTAINTY AS TO WHAT CAPABILITY REALLY EXISTS ON CURRENT RANGES, AND THIS SUGGESTS OTT&E CREDIBILITY QUESTIONS. WE STRONGLY RECOMMEND A COMPREHENSIVE IMPROVEMENT PROGRAM,AND YOU SEE A LIST OF POSSIBLE CANDIDATES. OUR COMMANDER, MAJ GEN T. W. MORGAN, HAS EXPRESSED HIS CONCERN TO GEN PHILLIPS IN A RECENT LETTER SUGGESTING THAT THESE DISCREPANCIES BE AIRED TO THE JOINT LOGISTIC COMMANDERS. FROM A PERSONAL VIEWPOINT, I SHOULD LIKE TO SEE THE AIR FORCE LEAD THE FIELD WITH A CALIBRATION STANDARDS PROGRAM, BUT IT MAY HAVE TO BE DONE AT DOD.

CONCLUSIONS

- SIGNIFICANT VOIDS EXIST IN RANGE CAPABILITIES
- SIGNIFICANT UNCERTAINTY AS TO REAL CAPABILITY THAT DOES EXIST
- SUGGESTS OTT&E CREDIBILITY QUESTIONS

RECOMMENDATIONS

- COMPREHENSIVE IMPROVEMENT PROGRAM
  - ~~TESPO~~
  - AGMC (AFR 74-2)
  - RML
  - NWC/PMTC
  - USATDA/NTEC
  - ADTC
  - SAMTEC
  - WSMR/DPG/YPG
- JOINT LOGISTICS COMMANDERS
  - BRING TO THEIR ATTENTION
  - SUGGEST JOINT PROGRAM OR USAF LED PROGRAM
- DOD - DDR&E (T&E) AND/OR ASD (I&L)
  - BRING TO THEIR ATTENTION
  - SUGGEST CAPABILITY FOR JOINT TESTS
  - SUGGEST JOINT PROGRAM OR USAF LED PROGRAM